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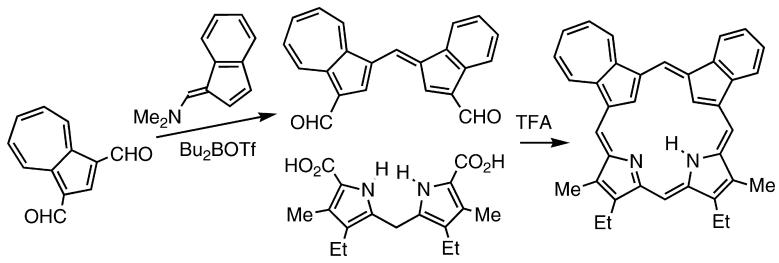

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Fulvene Dialdehyde Strategy for *adj*-Dicarbaporphyrinoid Synthesis: Preparation of a 22-Carbaazuliporphyrin

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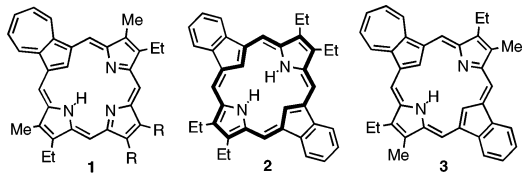
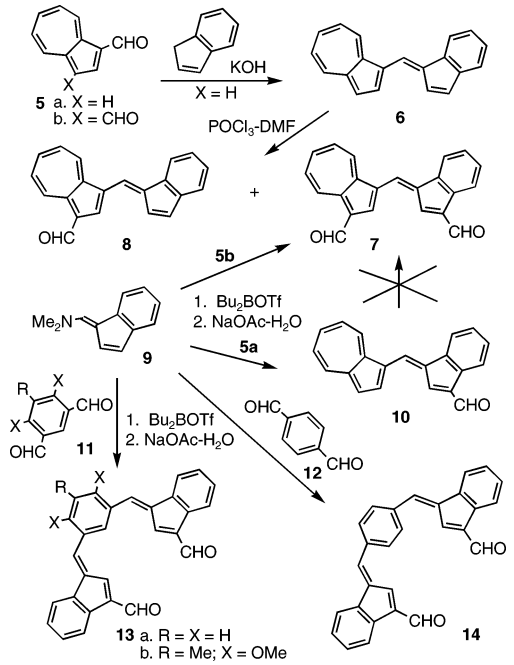
Carbaporphyrinoid systems are a particularly important group of porphyrin analogues where one or more of the usual pyrrole subunits have been replaced by carbocyclic rings.[1,2] They have been extensively investigated due to their unusual chemical and spectroscopic properties and their ability to form stable organometallic derivatives.[3] The cavities of the macrocycles have internal carbon atoms, and in this respect, they resemble the N-confused porphyrins[4] and related O- and S-confused porphyrinoids.[5] Many different monocarbaporphyrinoids are now known (e.g., azuliporphyrin **1**),[1,2] but few examples of dicarbaporphyrins have been described. Two examples of doubly N-confused porphyrins have been reported,[6] and these have been shown to form silver(III) and copper(III) complexes. We have previously reported the synthesis of three *opp*-dicarbaporphyrinoids where the macrocycle consists of alternating pyrrole and carbocyclic rings.[7−9] The first example of this type was dicarbaporphyrin **2**,[7] which was prepared from diformylindane and diethylpyrrole in a one-step procedure, and subsequently, 23-carbaazuliporphyrin **3**[8] and resorcinol-derived dicarbaporphyrins[9] were prepared using a "3 + 1" approach.[10] All of these syntheses rely upon the formation of carbon−carbon bonds by electrophilic substitution onto the pyrrolic intermediates. In order to synthesize dicarbaporphyrinoids with adjacent carbocyclic rings, a new strategy is required to generate suitable intermediates that have linked carbocyclic rings as well as the aldehyde units that will facilitate macrocycle formation. Fulvenes are valuable intermediates for synthetic[11] and organometallic applications,[12] although they have not previously been investigated for porphyrin analogue synthesis. However, structures of type **4** could potentially act as superior intermediates in the synthesis of di-, tri-, or even tetracarbaporphyrinoid systems.



Azulene-containing porphyrinoids have many interesting properties[13] including aromatic characteristics that fall midway between porphyrins and nonaromatic macrocycles.[14] Azulene also favors electrophilic substitution at the 1- and 3-positions, and this allows the convenient introduction of functional groups.[15] For instance, azulene is easily converted to the mono- or dialdehydes **5a** and **5b** by Vilsmeier−Haack formylation.[15] Monoaldehyde **5a** was shown to react with indene in the presence of KOH in methanol to give fulvene **6** (Scheme 1). Due to the conjugated nature of this system, it was anticipated that electrophilic substitution could be directed toward both termini of this unit to generate dialdehyde **7**. However,

Scheme 1



reaction of **6** with $POCl_3$ and DMF gave primarily the monoaldehyde **8**, and only a low yield of **7** was noted. Prolonged reaction times at elevated temperatures increased the yield of crude dialdehyde in small scale reactions to 27%, but this approach did not provide a practical route to this intermediate. Enamine **9** is easily prepared from indene and DMF dimethyl acetal,[16] and this system offers the possibility of directing attack onto an aldehyde while introducing a new formyl moiety on the indene unit. The reaction of **9** with aldehyde **5a** was investigated using Lewis acid catalysts such as $AlCl_3$, $SnCl_4$, $TiCl_4$, $(C_5H_5)_2TiCl_2$, $(C_5H_5)_2ZrCl_2$, and $Yb(OTf)_3$, but of these, only $TiCl_4$ gave even low yields of the required aldehyde **10**. However, Bu_2BOTf (1 equiv) in dichloromethane was subsequently found to be a superior catalyst, and following hydrolysis with aqueous sodium acetate solution, the fulvene aldehyde was isolated in 75% yield. Unfortunately, all attempts to formylate **10** failed to give dialdehyde **7**. Instead, azulene dialdehyde **5b** was reacted with 1 equiv of **9** in the presence of Bu_2BOTf to generate the elusive fulvene dialdehyde **7**. The product appeared to degrade during chromatography, but reasonably pure material could be isolated in 53% yield by recrystallization from acetone. Interestingly, reaction of 1 equiv of **9** with dialdehydes **11** or terephthalaldehyde (**12**) primarily afforded the difulvenes **13** and **14**, respectively. When the reactions were repeated using 2 equiv of **9**, the stable difulvenes were isolated in 52−84% yield. It remains to be seen whether difulvenes **13** and **14** can be utilized in the synthesis of tricarbaporphyrinoid systems.

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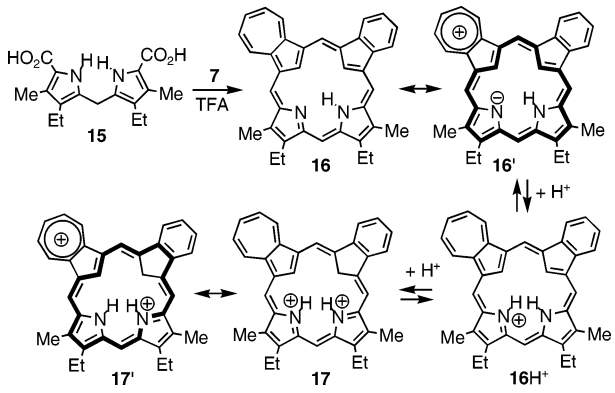
Scheme 2



Dialdehydes are commonly used in the MacDonald "2 + 2" synthesis of porphyrins,[10] although this method usually requires the oxidation of a dihydroporphyrinoid intermediate. Fulvene dialdehyde **7** is structurally compatible with this approach, but no oxidation step is required due to the fully conjugated nature of this structural unit. Reaction of dialdehyde **7** with dipyrrylmethane **15** was carried out in TFA/dichloromethane, and following neutralization, column chromatography on grade 3 alumina, and recrystallization from chloroform/hexanes, the novel *adj*-dicarbaporphyrinoid **16** was isolated in 19% yield (Scheme 2). The macrocycle can be considered to be a 22-carbaazuliporphyrin, and it is an isomer of the previously synthesized *opp*-dicarbaporphyrinoid **3**.[8] However, unlike **3**, **16** is a robust compound that shows little sign of decomposition even after several days in solution. The low solubility of **16** is chloroform led to poor quality proton NMR spectra in $CDCl_3$ at 25 °C, but a much better spectrum could be obtained at 50 °C. This spectrum shows that the macrocycle has significant diatropic character (Figure 1). The two internal CHs were observed upfield as 1H resonances at 1.6 and 3.5 ppm, while the NH could be seen as a very broad peak at 4.3 ppm. The *meso*-protons were similarly shifted downfield and gave four 1H singlets at 7.5, 8.0, 8.5, and 9.1 ppm. These values indicate that **16**, like azuliporphyrin and *opp*-dicarbaporphyrin **3**, has aromatic character approximately halfway between nonaromatic systems such as benziporphyrins[17] and fully aromatic macrocycles such as porphyrins.[1] This property presumably arises due to contributions from dipolar canonical forms such as **16′** which possess a tropylium unit and an 18π electron delocalization pathway. Addition of trace amounts of TFA to the NMR tube gave a poor quality NMR spectrum that corresponded to **16**H^+ where the inner CH resonances were shifted upfield to −1.2 and −2.1 ppm. However, further addition of TFA gave rise to the aromatic C-protonated dication **17**. This species also shows an enhanced diatropic ring current where the internal CH_2 gave a 2H singlet at −2.7 ppm, while the azulene CH gave a resonance at 0.0 ppm. The *meso*-protons were also shifted upfield, giving four 1H singlets at 9.5, 10.0, 10.3, and 10.4 ppm. The increased aromatic character is attributed to the beneficial charge delocalization that results from aromatic contributors such as **17′**. The UV−vis spectrum of **16** in chloroform showed four absorption bands in the Soret region between 350 and 500 nm that resemble the UV−vis spectrum of azuliporphyrin. Addition of TFA led to the formation of the diprotonated species **17** with a strong absorption band at 374 nm, but no intermediary species could be identified. Titration with TFA showed that the free base spectrum was directly replaced by species **17** and isosbestic points could be identified at 389, 432, and 509 nm. Although the monocation **16**H^+ had been observable by proton NMR spectroscopy, the species apparently cannot be seen in the far more dilute solutions used to run the UV−vis spectra. The same phenomenon was previously observed for the isomeric 23-carbaazuliporphyrin **3**.[8]

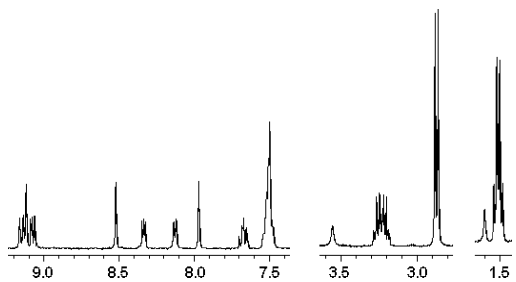


Figure 1. Proton NMR (400 MHz) spectrum of porphyrinoid **16** in $CDCl_3$ at 50 °C following a D_2O shake. This reveals the presence of a 1H singlet at 1.6 ppm.

In conclusion, a convenient methodology has been developed to synthesize fulvene aldehydes and related difulvenes. These stable conjugated systems are valuable synthetic intermediates, and their potential has been demonstrated by the synthesis of the first example of an *adj*-dicarbaporphyrinoid. Unlike the isomeric dicarbaporphyrinoid **3**, **16** is a stable system that will be amenable to detailed reactivity studies.

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Supporting Information Available: Experimental procedures and UV−vis, ^{1}H NMR, and ^{13}C NMR spectra for selected compounds are provided. This material is available free of charge via the Internet at http://pubs.acs.org.

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