

Organoiron Route to a New Dendron for Fast Dendritic Syntheses Using Divergent and Convergent Methods

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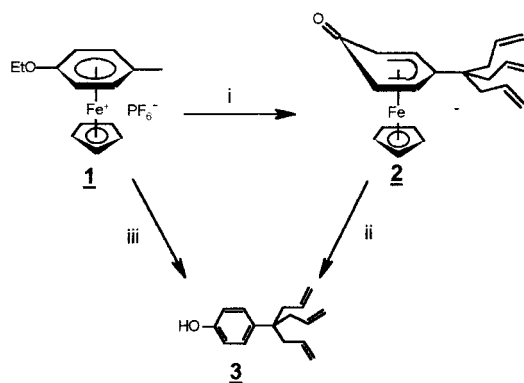
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The construction of dendrimers by organic¹ and inorganic² paths is well established. Although organotransition-metal moieties have been fixed onto the termini of dendrimers³ for catalytic applications,⁴ the only known organotransition-metal synthesis of dendrimers is Puddephatt's oxidative addition of benzyl halides to Pd(0) complexes.⁵ The syntheses of large dendrimers usually require a number of steps, which overtakes those involved in the total syntheses of natural products, thus the search for fast syntheses of large dendrimers is timely. We are reporting here the organoiron synthesis of a dendron involving eight steps of four different kinds in a one-pot reaction and the use of this dendron for the fast synthesis of dendrons and dendrimers using divergent and convergent routes.

We already know that the CpFe⁺-induced perfunctionalization of permethylaromatics by reaction with a base and a functional halide provides a clean and efficient route to dendritic cores (Cp = η⁵-C₅H₅).^{6a,b} We have now been able to combine this reaction with the CpFe⁺-induced heterolytic cleavage of the exocyclic

Scheme 1^a



^a (i) *t*-BuOK, THF, CH₂=CH-CH₂Br, 10d, -50 °C–rt, 50%; (ii) hν_{vis}, MeCN, 4h, rt, 70%; (iii) *t*-BuOK, THF, CH₂=CH-CH₂Br, 5d, -50 °C–rt, 60%.

C–O bond of aryl ethers^{6c} (Scheme 1). The iron complex **1** is easily available on a very large scale by quantitative reaction of ethanol and K₂CO₃ with [FeCp(η⁵-p-CH₃C₆H₄Cl)](PF₆).^{6b,7} Reaction of **1** with *t*-BuOK and allylbromide in THF directly provides good yields of either the iron complex **2** or the free phenol derivative **3**, depending on the reaction conditions. Note that this flexible and powerful combination is unprecedented. From **1**, the three deprotonation–allylation sequences occur before heterolytic cleavage of the C–O bond, giving **2**, a red oil, in 50% yield. Alternatively, addition of *t*-BuOK in situ instead of extraction of **2** provokes its decomplexation giving **3**, a light-brown solid, in 60% overall yield from **1** (after chromatography) in this one-pot reaction. Photolysis of isolated **2** in MeCN also leads to **3** (70% yield).⁸

The divergent construction starts from the nona-ol **6** synthesized by CpFe⁺ induced nona-allylation of mesitylene followed by hydroboration and oxidation of the nona-borane using H₂O₂/NaOH^{6c} (Scheme 2). Reaction of SiMe₃Cl, then NaI, with **6** gives the nona-iodo dendritic core **7**, a light-yellow solid, in 89% yield. Reaction of **7** with **3** and CsF in DMF leads to the first-generation 27-allyl dendrimer **9** which is purified by chromatography and characterized inter alia by the molecular peak in the MALDI TOF mass spectrum (MNa⁺ = 2558). However, peaks corresponding to the 24- and 21-allyl dendrimers are also observed, corresponding to some dehydroiodation of iodoalkyl branches. Thus, we switched to the mesylation of **6** using mesylchloride, which gives the nona-mesylate **8** (95% yield). Reaction of **8** with **3** and CsF in DMF followed by column chromatography gives **9** (27% yield) whose MALDI TOF mass spectrum shows only tiny amounts of impurities. Iteration of this reaction sequence followed by chromatography gives the second-generation 81-allyl dendrimer **10** whose MALDI TOF mass spectrum shows the molecular peak MNa⁺ at 5989, although several other less intense peaks were also found, corresponding mainly to the side deshydroimesylation. The synthesis of the third dendritic generation, 243-allyl dendrimer **11** was also attempted. Monitoring by NMR the reaction of the 81-mesylate dendrimer (obtained in 45% overall yield from **10**) showed the progressive disappearance of the mesylate functional groups until completion and their replacement by phenate triallyl

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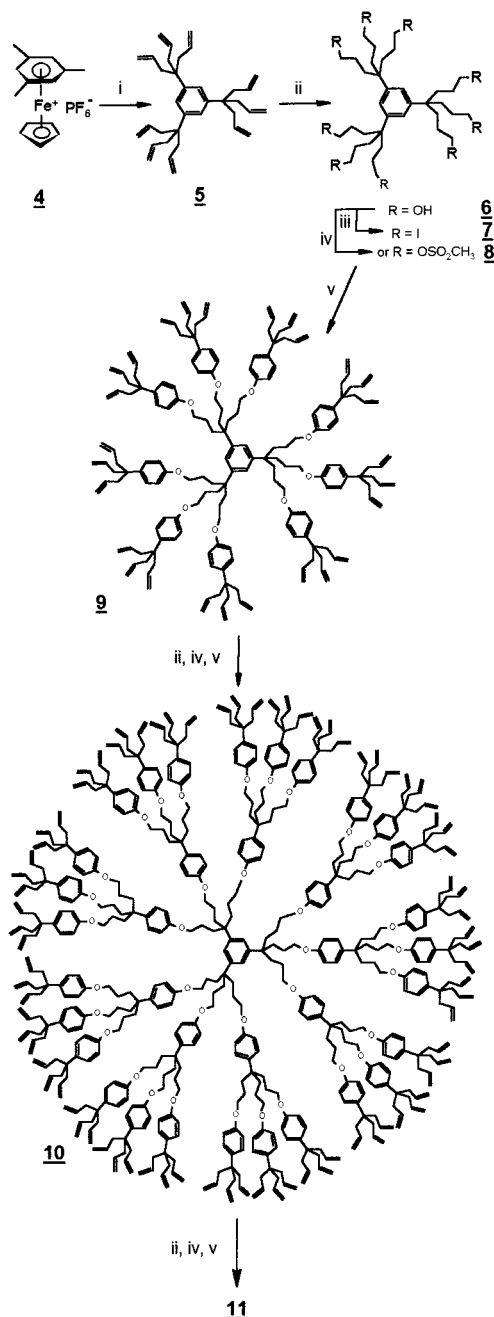
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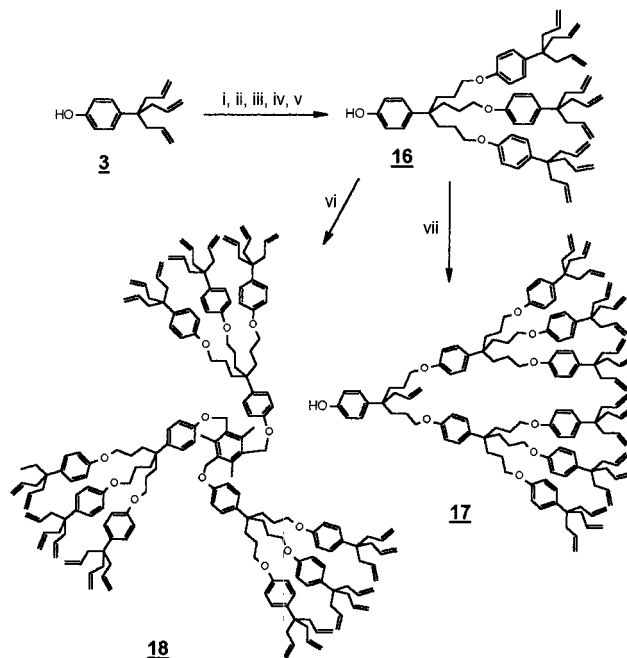
Scheme 2. Divergent Dendrimer Syntheses^a

^a Syntheses involve the following steps from one generation to the next: $\text{RCH}=\text{CH}_2 \xrightarrow{\text{(ii)}} \text{RCH}_2\text{CH}_2\text{OH} \xrightarrow{\text{(iv)}} \text{RCH}_2\text{CH}_2\text{OSO}_2\text{Me} \xrightarrow{\text{(v)}} \text{RCH}_2\text{CH}_2\text{OPhC(allyl)}_3$ (i) KOH, DME, $\text{CH}_2=\text{CH}-\text{CH}_2\text{Br}$, 10 d, rt; then $h\nu_{\text{vis}}$, PPh_3 , MeCN, 12 h, rt. (ii) Disiamylborane, THF 0 °C, then H_2O_2 , NaOH 3 N, 50 °C, 88%. (iii) Me_3SiCl , NaI, MeCN, 80 °C, 12 h, 89%. (iv) MeSO_2Cl , py, 0 °C, 5 h, 95%. (v) **3**, CsF, DMF, rt.

moieties. Although the ^1H and ^{13}C NMR spectra were finally in agreement with the 243-allyl structure of **11**, a clean mass spectrum could not be obtained, possibly due to the polydispersity⁹ of this dendrimer.

The successful convergent synthesis of the nona-allyl dendron **16** is achieved by reaction of **3** with the tri-iodoalkyl derivative obtained according to Scheme 3 (30% overall yield of **16** from **3** after chromatography; MALDI TOF mass spectrum: $[\text{M} + \text{Na}^+] = 935.6$, no side peak). Reaction of **16** with this same tri-

(9) Recently, Newkome et al. introduced the terms monomolecular and monodisperse dendrimers for structures with 100 and <100% dendritic purity, respectively: Newkome, G. R.; Weiss, C. D.; Morefield, C. N. *Macromolecules* **1997**, *30*, 2300.

Scheme 3. Convergent Dendrimer Routes^a

^a Routes involve the following steps for the synthesis of the protected trifunctional dendron which reacts with **3** to provide the protected precursor of **16**: **3** $\xrightarrow{\text{(i)}}$ $\text{MeOPhC}(\text{CH}_2-\text{CH}=\text{CH}_2)_3 \xrightarrow{\text{(ii)}}$ $\text{MeOPhC}\{(\text{CH}_2)_3\text{OH}\}_3 \xrightarrow{\text{(iii)}}$ $\text{HOPhC}\{(\text{CH}_2)_3\text{I}\}_3 \xrightarrow{\text{(iii)}}$ $\text{C}_2\text{H}_5\text{C}(\text{O})\text{OPhC}\{(\text{CH}_2)_3\text{I}\}_3$ (i) MeI, KOH, DMSO, 2 h, rt, 91%. (ii) Disiamylborane, THF, then H_2O_2 , NaOH 3 N, 50 °C, 89%. (iii) Me_3SiCl , NaI, MeCN, 12 h, 80 °C, 87%. (iv) $\text{EtC}(\text{O})\text{I}$, $\text{NEt}_3\text{-Pr}_2$ (1 equiv), CH_2Cl_2 , 16 h, rt, 94%. (v) **3**, K_2CO_3 , DMF, 2 d, rt, 30%, then K_2CO_3 , H_2O . (vi) K_2CO_3 , Me_2CO , 2 d, reflux, 2,4,6-tri(bromomethyl)mesitylene, 33%. (vii) **15**, K_2CO_3 , DMF, then K_2CO_3 , H_2O , 2 d, rt, 35%.

iodoalkyl-protected phenol does not lead to the expected 27-allyl dendron but to the 19-allyl dendron **17** (35% yield after chromatography) resulting from the selective dehydroiodation of one iodoalkyl branch. Thus, condensation of **16** is faster than dehydroiodation for the first two branches, but this latter reaction is faster than the condensation of **16** onto the third branch for steric reasons. The selectivity is remarkable, as shown by the purity of the product disclosing a clean MALDI TOF mass spectrum without side peaks ($[\text{M} + \text{Na}^+] = 2077.7$). Finally another example of the rich potential of the dendrons **3** and **16** is provided by the reaction of **16** with 2,4,6-tri(bromomethyl)mesitylene giving the 27-allyl dendrimer **18** (MALDI TOF mass spectrum: $\text{MK}^+ = 2935.9$). The polyolefin dendrimers are colorless or light-brown oils, the polyomesylate dendrimers are colorless oils, and the polyol dendrimers are white solids.

In conclusion, using a one-pot organoiron-mediated reaction which involves eight successive steps, we have synthesized a new tripodal dendron and shown its broad synthetic potential for the fast divergent and convergent syntheses of polyallyl dendrons and dendrimers. Exploration of the numerous facets of the synthetic potential of this dendritic chemistry is currently underway in our laboratories.

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Supporting Information Available: Experimental procedures, spectroscopic and analytical data, and MALDI TOF and ^1H and ^{13}C NMR spectra for the new compounds (PDF). This material is available free of charge via the Internet at <http://pubs.acs.org>.

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