Enhanced Nucleophilic Reactivity of a 4-Lithiophenoxide Ion and Its Application to the Synthesis of a Bis(4-hydroxyphenyl)methylenecyclopentadiene and Its Dianion, a Novel Extended Trimethylenemethane Dianion

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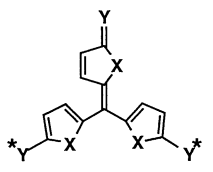
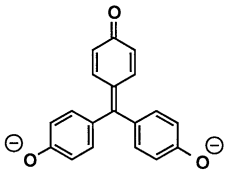
2,6-Di-*tert*-butyl-4-lithiophenoxide ion has enhanced nucleophilic reactivity probably due to intramolecular electronic repulsion and its reaction with 6,6-bis(dimethylamino)fulvene affords a novel extended trimethylenemethane dianion with a fulvene moiety whose NMR spectra indicate substantially strong tetrapolar properties.

Recently we have reported the synthesis and highly tetrapolar properties of some new trimethylenemethane di-ions extended with aromatic rings (general formula **1**).[1,2] Long known dianion **2** of aurin, 4-[bis(4-hydroxyphenyl)methylene]-2,5-cyclohexadien-1-one,[3] can also be regarded as a member of **1**. There are conceivable a good variety of this type of molecules and they are expected to constitute a novel class of dications, diradicals, and dianions with favorable stability. Here we wish to report the synthesis and some properties of bis(3,5-di-*tert*-butyl-4-hydroxyphenyl)methylenecyclopentadiene **3**, a novel fulvene derivative, and its dianion **4** which is isoelectronic to **2**, by taking advantage of enhanced nucleophilic reactivity of a 4-lithiophenoxide ion.



1

X = S or CH=CH
Y = methylene, heteroatom etc.
* = ⊕ or ⊖



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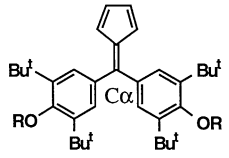
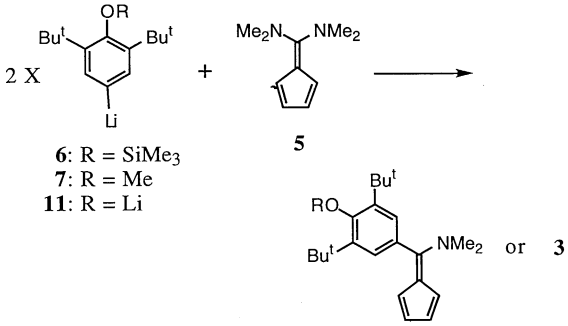


3: R = H
4: R = ⊖

According to a semiempirical molecular orbital calculation (PM-3),[4] the central quaternary carbon (Cα) of the unsubstituted compound of **4** bears considerable positive charge (+0.323) that is slightly more positive than Cα of **2** (+0.316).

A simple approach to **3** would be nucleophilic substitution reaction on 6,6-bis(dimethylamino)fulvene **5**.[5,6] However, the reaction of **5** with either 4-trimethylsilyloxy- or 4-methoxy-3,5-di-*tert*-butylphenyllithium, **6** or **7**, gave only the mono-substitution product, **8**[7] or **9**,[8] in moderate yields (44% or 50%) even under the use of excess reagent (Scheme 1). In view of rather poor electrophilic nature of **5** and steric congestion of trimethylsililated **8** and **9** for the second substitution, we thought stronger nucleophilicity might be required for the desired disubstitution. It was expected that 2,6-di-*tert*-butyl-4-lithiophenoxide ion **11**, to be generated from 2,6-di-*tert*-butyl-4-bromophenol **10** without protection of the hydroxy group, should be a stronger nucleophile than **6** and **7** owing to intramolecular electronic repulsion. Although generation and reactions of a few 4-lithiophenoxide ions other than **11** have been described,[9-11] their enhanced nucleophilic reactivity has not been noted. We therefore at first examined the nucleophilic reactivity of **11**.



6: R = $SiMe_3$
7: R = Me
11: R = Li

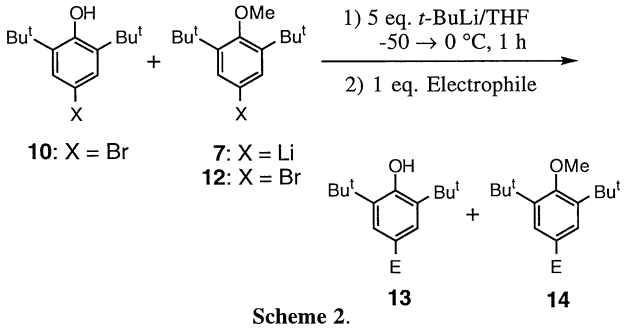
5

8: R = H[7]
9: R = Me

Scheme 1.

Phenol **10** was not effectively dilithiated with 2 equiv. of n-BuLi in THF up to 0 ℃ but smoothly dilithiated with 3 equiv. of *t*-BuLi at -50 to 0 ℃ to form **11**. Table 1 summarizes the results of competitive reactions of **11** and **7** with weak or moderate electrophiles (Scheme 2).[12] Thus, dianion **11** shows higher reactivity than monoanion **7** by 1.4-2.4 times of reaction rate based on the product ratios.

With this enhanced reactivity, the reaction of **11** (2 equiv.) and **5** at 0 ℃ to room temperature successfully afforded **3**[8] in 49% yield after neutralization. In addition to the electronically enhanced reactivity, the *tert*-butyl groups of **11** seem also to play a role for the successful formation of **3**, because the use of unsubstituted 4-lithiophenoxide[9] failed to give the parent compound of **3**.



10: X = Br
7: X = Li
12: X = Br

13 **14**

Scheme 2.

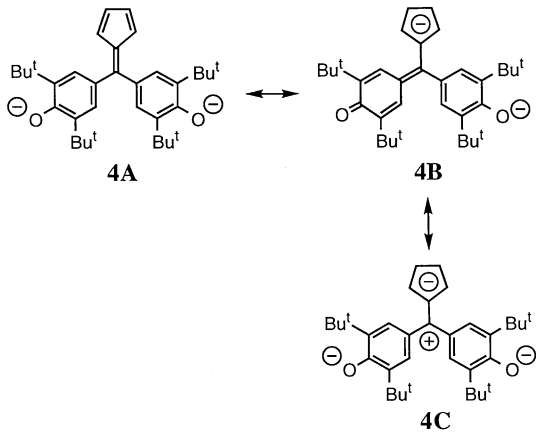
Table 1. Competitive reactions of **7** and **11** with electrophiles

Electrophile	E	Yield/%[a]		Ratio
		13	**14**	**13/14**
PhSSPh	PhS	56	39	1.4
Ph_2CO	Ph_2COH	52	33	1.6
$PhCONEt_2$	PhCO	61	26	2.4
PhCN	PhCO[b]	61	25	2.4

[a]Isolated yield. [b]After hydrolysis with acid.

Fulvene **3**[8] is a stable, reddish orange, crystalline substance. Treatment of **3** with sodium hydride in DMSO or THF affords dianion **4**[8] in deep red solution. The NMR spectra of **3** and **4** at ambient temperature show C_{2v} symmetry of the molecules. All the protons of **4** are shifted up-field by 0.1 to 0.5 ppm relative to those of **3**, in particular, the protons in the five-membered ring showing the largest up-field shift (δ 6.37 and 6.59 of **3** vs. 5.99 and 6.08 of **4**). The summed ^{13}C chemical shift of the five-membered ring of **3** (Σδ = 650.4 ppm) is only slightly smaller (up-field shift) than that of 6,6-diphenylfulvene (Σδ = 654.9 ppm)[13] to indicate only a small electron-donating effect of the *para*-hydroxyphenyl groups on the fulvene moiety. On the other hand, Σδ of **4** (593.4 ppm) is 57 ppm smaller than that of **3**, corresponding to the increase of negative charge of approximately 0.35 unit in the five-membered ring.[14] In contrast to this up-field shift, the central carbon Cα of **4** (δ 163.61) is at 8.35 ppm lower field than of that of **3** (δ 155.26) despite dianionic nature of the molecule.

These NMR results, coupled with in itself dipolar property of neutral fulvenes bearing some positive charge on the exomethylene carbon, point to significantly large resonance contribution of the tetrapolar structure **4C** relative to **4A** and **4B**; however, the resonance contribution of **4C** seems not very large, because its visible absorptions show bathochromic shift in polar solvents (λ_{max} 516 nm/DMSO; 499 nm//THF).



Upon cyclic voltammetry (DMF, room temp.), fulvene **3** showed one oxidation wave and two reduction waves with poor reversibility at +1.31 V, -1.64 V, and -2.15 V (peak potential vs. Ag/AgCl; ferrocene/ferrocenium = +0.45 V), whereas dianion **4** did one oxidation wave at low potential of +0.25 V and two reduction waves at appreciably high potential of -2.06 V and -2.43 V (peak potentials). The oxidation wave of **4** appears to involve two-electron transfer, since its integrated area is nearly twice of those of the reduction waves. This suggests the ready formation of the corresponding diradical by oxidation and more difficult formation of the corresponding trianion radical and tetraanion.

Further synthetic application of **11** and studies on the radical species from **4** are in progress.

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References and Notes

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8 Selected physical data for products: **3**: reddish orange plates, mp 172-173 °C; ^1H NMR (270 MHz, $CDCl_3$) δ 1.42 (18H, s), 5.40 (2H, s, OH), 6.37 and 6.59 (AA'BB'), 7.18 (4H, s); ^{13}C NMR (67.8 MHz, $CDCl_3$) δ 30.43, 34.36, 124.58, 130.08, 130.57, 132.60, 134.94, 141.05, 155.26; UV-Vis (DMSO) λ_{max} (log ε) 257 (4.10), 343 sh (4.11), 381 (4.26), 545 (3.09). **4**: ^1H NMR (270 MHz, DMSO-d_6) δ 1.32 (18H, s), 5.99 and 6.08 (AA'BB'), 7.08 (4H, s); ^{13}C NMR (67.8 MHz, DMSO-d_6) δ 30.07, 34.72, 116.28, 116.44, 120.40, 127.93, 132.38, 134.68, 163.61, 175.62. **8**: pale yellow plates, mp 155 °C (dec.); ^1H NMR (270 MHz, $CDCl_3$) δ 1.43 (18H, s), 3.24 (6H, s), 5.38 (1H, s), 5.81 (1H, m), 6.19 (1H, m), 6.51 (1H, m), 6.74 (1H, m), 7.11 (2H, s). **9**: yellow plates, mp 116-117 °C; ^1H NMR (270 MHz, $CDCl_3$) δ 1.42 (18H, s), 3.20 (6H, s), 3.71 (3H, s), 5.79 (1H, m), 6.21 (1H, m), 6.54 (1H, m), 6.75 (1H, m), 7.19 (2H, s).
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