

Silver Ion-Mediated Coupling of 4-Bromo-2,6-di-*tert*-butylcyclohexa-2,5-dienone with Phenols

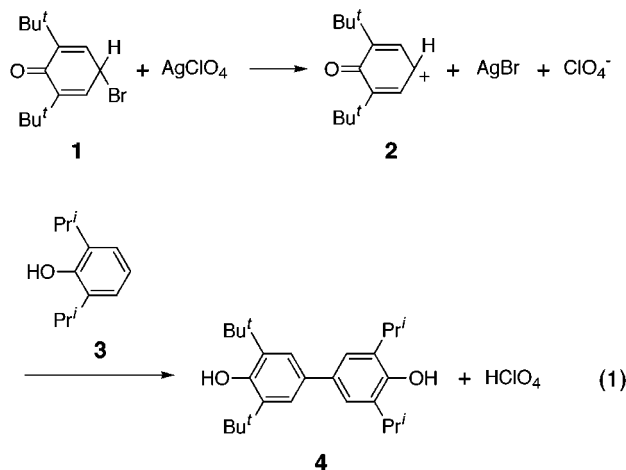
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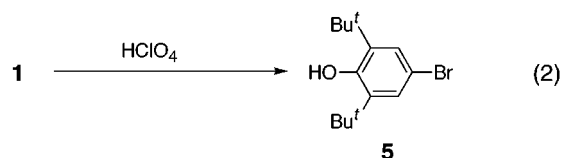
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Recently, we have shown that the Ag ion can induce nucleophilic displacement of 4-bromo-2,6-di-*tert*-butylcyclohexa-2,5-dienone (**1**) with alcohols.¹ We were then prompted to study the Ag ion-promoted displacement of **1** with phenolic nucleophiles. The products expected were 3,5-di-*tert*-butyl-4,4'- or 4,2'-biphenols which are not easily accessible by the conventional coupling reactions. This paper deals with the results of such a study.

Compound **1** was allowed to react at 0 °C for a short period with excess 2,6-diisopropylphenol (**3**) (4 mol equiv) in DME containing AgClO₄ (1 molar equiv). 3,5-Di-*tert*-butyl-3',5'-diisopropyl-4,4'-biphenol (**4**) was, as anticipated, obtained in 37% yield (eq 1).² The major product

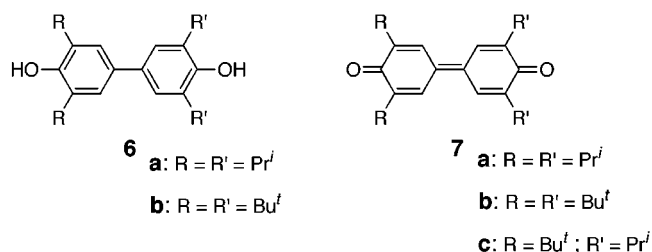


was 4-bromo-2,6-di-*tert*-butylphenol (**5**) (47%). A small amount of 2,6-di-*tert*-butylphenol (**8**) (6%) was also produced. Prototropic rearrangement of **1** to give **5** was presumed to have been caused by catalysis with HClO₄, which was likely generated during the course of the reaction (eq 2, cf. eq 1). Neutralization of the HClO₄ as it was generated, therefore, was expected to suppress the



formation of **5**. The AgClO₄-induced reaction of **1** with **3**

in DME was carried out in the presence of excess Na₂CO₃ (4 molar equiv), and the formation of **5** was found to be indeed minimized (3%), while that of **4** was substantially increased (60%).³ Symmetrically substituted 4,4'-biphenols **6a** or **6b** were not obtained. 4,4'-Diphenoquinones **7a**, **7b**, or **7c**, the products of dehydrogenation of **6a**, **6b**, or **4**, respectively, were not obtained either.



The success of preparation of **4** led us to investigate the coupling of **1** with other phenols by using AgClO₄/Na₂CO₃ in DME. The phenolic nucleophiles chosen were mainly alkyl-substituted ones. The results are shown in Table 1. From 4-unsubstituted 2,6-dialkylphenols **8**, **9**, **11**, **13** and **15**, 3,5-di-*tert*-butyl-3',5'-dialkyl-4,4'-biphenols **6b**, **10**, **12**, **14**, and **16**, respectively, were generated in 50–68% yield. The coupling with 6-unsubstituted 2,4-dialkylphenols **17**, **20**, and **22** afforded 3,5-di-*tert*-butyl-3',5'-dialkyl-4,2'-biphenol **19**, **21**, and **24**, respectively, in 53–69% yield, along with the 3,5-di-*tert*-butyl-4-phenoxyphenols, the products of C–O coupling, as the minor products. From the reaction of 2,6-unsubstituted 4-alkylphenols **25** and **28**, both the 4,2'-biphenols and the 4-phenoxyphenols were produced, the amounts of the latter products having been principal or substantial. All of the three possible coupling products, **34**, **35**, and **36**, were obtained from the reaction of 3,5-dimethylphenol (**33**). In contrast, the reaction of 3,5-di-*tert*-butylphenol (**31**) afforded only 4-phenoxyphenol **32**. Neither the 4,4'-nor the 4,2'-biphenol was produced. Bulky *tert*-butyl groups at the 3- and 5-positions in **31** may prohibit attack by cation **2** on the ring carbons. While no or little C–O coupling took place in the reaction of 4-unsubstituted 2,6-dimethylphenols **9**, **13**, and **15**, the reaction of 2,4,6-trimethylphenol (**37**) gave 4-phenoxyphenol **38**, albeit in a fair yield.

The reaction of some phenols bearing a substituent(s) other than an alkyl group was also investigated. The reaction of 2,6-dimethoxyphenol (**39**) afforded 4,4'-biphenol **40**. 4,3'-Biphenol **41** and 4,4'-diphenoquinones **42** and **7b** were obtained in addition. The obtention of **41** as the principal C–C coupling product may probably indicate that the 3- and 5-positions in **39** are the most activated sites toward electrophilic attack by cation **2**. Bromination of **39** with Br₂ has been reported to give 3-bromo-2,6-dimethoxyphenol exclusively or almost exclusively rather than the 4-bromo isomer.⁴ The reaction of 4-chlorophenol (**43**), 4-acetylphenol (**46**), and 4-nitrophenol (**49**) gave both the expected 4-phenoxyphenols and the 4,2'-biphe-

(3) The reaction with 2 molar equiv (in place of 4 mol equiv) of **3** gave **4** in 49% yield.

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(2) A similar reaction with AgOCOCF₃, another Ag salt soluble in DME, in place of AgClO₄ provided only a few percent of **4**. The ¹H NMR spectrum of the crude reaction product suggested that it contained significant amounts of 4-(trifluoroacetoxy)-2,6-di-*tert*-butylphenol and its tautomer, 4-(trifluoroacetoxy)-2,6-di-*tert*-butylcyclohexa-2,5-dienone. Cf. ref 1.

Table 1. Coupling of Bromo Dienone **1** with Phenols

| phenol | product (yield, %) | | phenol | product (yield, %) | |
|---------------|--------------------|--------------------|---------------|--------------------|--------------------|
| | C-O coupling | C-C coupling | | C-O coupling | C-C coupling |
| 3 | | 4 (60) | 31 | 32 (78) | |
| 8 | | 6b (57) | 33 | 34 (19) | 35 (23) |
| 9 | | 10 (57) | | | |
| 11 | | 12 (61) | | | 36 (45) |
| 13 | | 14 (68) | 37 | 38 (35) | |
| 15 | | 16 (50) | 39 | | 40 (22) |
| 17 | 18 (9) | 19 (60) | | | 41 (39) |
| 20 | N. E. ^a | 21 (69) | | | 42 (7) |
| 22 | 23 (12) | 24 (53) | 43 | 44 (57) | 45 (23) |
| 25 | 26 (67) | 27 (27) | 46 | 47 (23) | 48 (18) |
| 28 | 29 (30) | 30 (39) | 49 | 50 (32) | 51 (4) |

^a Not examined.

nols. However, the total yields of the coupling products obtained from the strongly deactivated phenols (**46** and **49**) were limited.

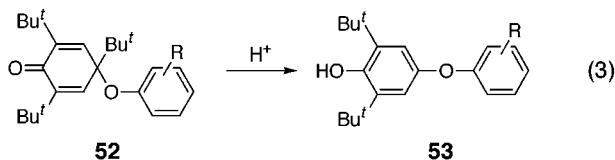
Of the biphenolic products listed in Table 1, symmetrically substituted 4,4'-biphenol **6b** can be prepared by dehydrogenative dimerization of **8**.⁵ The other biphenols (except **41**) may in principle be producible by a one-electron cooxidation of **8** and the appropriate phenols.

The biphenols from this cross-coupling, however, may necessarily be accompanied by the biphenolic products from dehydrogenative dimerization of **8** and/or of the phenols employed. Moreover, further dehydrogenation of

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the biphenolic products to give the diphenoquinones may not be avoided. As a result, formation of the biphenols by the cross-coupling may not be very selective. For instance, cooxidation of **8** with **9**, **15**, or **39** with manganese complexes has been shown to give mixtures of products, from which **10**, **16**, or **40**, respectively, are isolable in low yields.⁶

A convenient method for preparation of 3,5-di-*tert*-butyl-4-phenoxyphenols **53** may be the acid-catalyzed de-*tert*-butylation of 2,4,6-tri-*tert*-butyl-4-phenoxy-cyclohexa-2,5-dienones **52** (eq 3),⁷ which are obtained by reaction of 2,4,6-tri-*tert*-butylphenoxy radical with phenols.⁸ Indeed **32** has been prepared by using this method.⁷ It



should, however, be noted that the reaction to give **52** does not always proceed smoothly.⁹ In addition, selectivity of the formation of **53** from **52** is not always high.⁷

The results shown above may suffice to prove that **1** can couple with a wide variety of phenols when mediated by $\text{AgClO}_4/\text{Na}_2\text{CO}_3$. Exhaustive de-*tert*-butylation of the coupling products obtained here may be expected to furnish a number of new 4,4'- and 2,4'-biphenols as well as 4-phenoxyphenols.¹⁰

Experimental Section

¹H (90 MHz) and ¹³C (22.6 MHz) NMR and IR spectra were taken in CDCl_3 and in CHCl_3 , respectively. Column chromatography was conducted on Merck SiO_2 60 using gradient elution (100% petroleum ether to 100% benzene). TLC was run on SiO_2 . GC analyses were performed at 150 °C on a column packed with 10% FAP-S on Chromosorb W.

General Procedure for Reactions in Table 1. To a mixture of powdered 4-bromo-2,6-di-*tert*-butylcyclohexa-2,5-dienone (**1**) (570 mg, 2 mmol) and finely powdered anhydrous Na_2CO_3 (0.85 g, 8 mmol) was added in one portion a cold (0 °C) solution of a phenol (8 mmol) and AgClO_4 (415 mg, 2 mmol) in DME (10 mL), and the resulting mixture was stirred magnetically for 10 min at 0 °C. The mixture was filtered into a flask containing water. The contents of the flask were extracted with ether. The extract was washed with water, dried over anhydrous Na_2SO_4 , and evaporated to dryness. The residue was chromatographed. The residues obtained from the reactions of 2,6-dimethylphenol (**9**), 2,3,6-trimethylphenol (**13**), and 2,3,5,6-tetramethylphenol (**15**) were sublimed (85 °C, 21 mmHg) to recover the unreacted phenols as the sublimates, and the residues were chromatographed. The residue obtained from the reaction of 2,6-dimethoxyphenol (**39**) was washed with petroleum ether, affording 3,5-di-*tert*-butyl-3',5'-dimethoxy-4,4'-diphenoquinone (**42**) as purple crystals (50 mg, 7%): mp 240–242 °C (lit.¹¹ mp 240–242 °C). The washings were evaporated, and the residue was chromatographed. Chromatography of the residue obtained from the reaction of 2,6-diisopropylphenol (**3**) provided, as the first fraction, a mixture of 2,6-di-*tert*-butylphenol (**8**) (35

mg, 8%) and 2,6-di-*tert*-butyl-4-bromophenol (**5**)^{5a} (18 mg, 3%) as analyzed by GC and ¹H NMR spectroscopy.

3,5-Di-*tert*-butyl-3',5'-diisopropyl-4,4'-biphenol (4): 460 mg (60%) from **3**; colorless crystals from hexane; mp 150–151.5 °C; ¹H NMR δ 7.31 (s, 2 H), 7.18 (s, 2 H), 5.16 (s, 1 H), 4.74 (s, 1 H), 3.20 (hept, $J = 6.8$ Hz, 2 H), 1.49 (s, 18 H), 1.32 (d, $J = 7.0$ Hz, 12 H); ¹³C NMR δ 152.7, 148.8, 135.8, 134.9, 133.5, 133.4, 123.7, 122.3, 34.4, 30.3, 27.4, 22.7; IR 3610, 3590 cm^{-1} . Anal. Calcd for $\text{C}_{26}\text{H}_{38}\text{O}_2$: C, 81.62; H, 10.01. Found: C, 81.37; H, 10.16.

3,5,3',5'-Tetra-*tert*-butyl-4,4'-biphenol (6b): 465 mg (57%) from **8**; light yellow crystals from hexane, identical with an authentic sample^{5c} (¹H NMR and TLC); mp 185–186.5 °C (lit.^{5c} mp 184.5–185.5 °C); ¹H NMR δ 7.30 (s, 4 H), 5.15 (s, 2 H), 1.49 (s, 18 H); ¹³C NMR δ 152.6, 135.8, 133.7, 123.9, 34.4, 30.3.

3,5-Di-*tert*-butyl-3',5'-dimethyl-4,4'-biphenol (10): 374 mg (57%) from **9**; light yellow crystals from EtOH; mp 198.5–200 °C (lit.⁶ mp 198.5–200 °C). The ¹H NMR and IR spectra were in accordance with those reported for **10**.⁶ ¹³C NMR δ 152.7, 151.0, 135.9, 134.5, 132.4, 127.1, 123.5, 123.0, 34.4, 30.4, 16.0. Anal. Calcd for $\text{C}_{22}\text{H}_{30}\text{O}_2$: C, 80.93; H, 9.26. Found: C, 80.85; H, 9.42.

3,5,3'-Tri-*tert*-butyl-5'-methyl-4,4'-biphenol (12): 450 mg (61%) from 2-*tert*-butyl-6-methylphenol (**11**); colorless crystals from hexane; mp 177–178 °C; ¹H NMR δ 7.30 (s, 2H), 7.26 (d, $J = 2.3$ Hz, 1 H), 7.13 (d, $J = 2.3$ Hz, 1 H), 5.15 (s, 1 H), 4.71 (s, 1 H), 2.29 (s, 3 H), 1.48 (s, 18 H), 1.46 (s, 9 H); ¹³C NMR δ 152.6, 151.4, 135.8, 135.5, 134.1, 133.0, 127.0, 123.9, 123.6, 123.0, 34.6, 34.4, 30.3, 29.8, 16.1; IR 3615, 3590 cm^{-1} . Anal. Calcd for $\text{C}_{25}\text{H}_{36}\text{O}_2$: C, 81.47, H, 9.85. Found: C, 81.32; H, 9.82.

3,5-Di-*tert*-butyl-2',3',5'-trimethyl-4,4'-biphenol (14): 459 mg (68%) from **13**; colorless crystals from hexane; mp 137.5–138 °C; ¹H NMR δ 7.06 (s, 2 H), 6.90 (s, 1 H), 5.13 (s, 1 H), 4.59 (s, 1 H), 2.24 (s, 6 H), 2.16 (s, 3 H), 1.46 (s, 18 H); ¹³C NMR δ 152.1, 150.6, 135.4, 135.1, 133.4, 132.8, 129.3, 126.1, 122.1, 119.5, 34.4, 30.4, 17.5, 15.8, 12.3; IR 3615, 3590 cm^{-1} . Anal. Calcd for $\text{C}_{23}\text{H}_{32}\text{O}_2$: C, 81.13; H, 9.47. Found: C, 80.93; H, 9.72.

3,5-Di-*tert*-butyl-2',3',5',6'-tetramethyl-4,4'-biphenol (16): 357 mg (50%) from **15**; colorless crystals from hexane; mp 208–210 °C (lit.⁶ mp 199–200 °C). The ¹H NMR and IR spectra were in accordance with those reported for **16**.⁶ ¹³C NMR δ 151.8, 150.3, 135.7, 135.4, 133.1, 133.1, 126.2, 118.8, 34.4, 30.6, 17.9, 12.3.

3,5-Di-*tert*-butyl-4-(2,4-di-*tert*-butylphenoxy)phenol (18): 76 mg (9%) from 2,4-di-*tert*-butylphenol (**17**); colorless oil; ¹H NMR δ 7.37 (d, $J = 2.6$ Hz, 1 H), 7.06 (dd, $J = 2.4$ Hz, 8.6 Hz, 1 H), 6.83 (s, 2 H), 6.59 (d, $J = 8.6$ Hz, 1 H), 4.94 (s, 1 H), 1.47 (s, 9 H), 1.41 (s, 18 H), 1.31 (s, 9 H); ¹³C NMR δ 155.0, 149.5, 148.8, 143.6, 137.9, 137.2, 123.7, 123.2, 116.7, 116.2, 34.9, 34.5, 34.3, 31.6, 30.2, 30.1; IR 3620 cm^{-1} . HRMS calcd for $\text{C}_{28}\text{H}_{42}\text{O}_2$ 410.3185, found 410.3159.

3,5,3',5'-Tetra-*tert*-butyl-4,2'-biphenol (19): 495 mg (60%) from **17**; colorless crystals from MeOH, identical with an authentic sample¹² (¹H and ¹³C NMR, IR and TLC); mp 189–190.5 °C (lit.¹² mp 189–190.5 °C).

3,5,3'-Tri-*tert*-butyl-5'-methyl-4,2'-biphenol (21): 511 mg (69%) from 2-*tert*-butyl-4-methylphenol (**20**); colorless crystals from hexane; mp 137.5–139 °C; ¹H NMR δ 7.20 (s, 2 H), 7.06 (d, $J = 2.3$ Hz, 1 H), 6.9–6.8 (m, 1 H), 5.41 (s, 1 H), 5.28 (s, 1 H), 2.30 (s, 3 H), 1.46 (s, 18 H), 1.44 (s, 9 H); ¹³C NMR δ 153.4, 148.8, 136.8, 135.4, 129.3, 128.3, 128.2, 128.0, 126.6, 126.0, 34.8, 34.5, 30.3, 29.7, 20.8; IR 3615, 3525 cm^{-1} . Anal. Calcd for $\text{C}_{25}\text{H}_{36}\text{O}_2$: C, 81.47; H, 9.85. Found: C, 81.32; H, 9.94.

3,5-Di-*tert*-butyl-4-(2,4-dimethylphenoxy)phenol (23): 77 mg (12%) from 2,4-dimethylphenol (**22**); light yellow oil; ¹H NMR δ 7.1–6.6 (m, 3 H), 6.79 (s, 2 H), 4.89 (s, 1 H), 2.28 (s, 3 H), 2.25 (s, 3 H), 1.40 (s, 18 H); ¹³C NMR δ 153.7, 149.5, 149.1, 137.2, 131.6, 131.5, 127.0, 116.9, 115.1, 34.5, 30.2, 20.6, 16.2; IR 3620 cm^{-1} ; HRMS calcd for $\text{C}_{22}\text{H}_{30}\text{O}_2$ 326.2247, found 326.2238.

3,5-Di-*tert*-butyl-3',5'-dimethyl-4,2'-biphenol (24): 346 mg (53%) from **22**; colorless crystals from hexane; mp 167.5–169 °C; ¹H NMR δ 7.21 (s, 2 H), 7.0–6.8 (m, 2 H), 5.28 (s, 1 H), 5.20 (s, 1 H), 2.27 (s, 6 H), 1.46 (s, 18 H); ¹³C NMR δ 153.4, 148.3, 136.7, 130.4, 128.8, 128.1, 127.9, 125.6, 123.9, 34.5, 30.3, 20.4,

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16.1; IR 3620, 3535 cm^{-1} . Anal. Calcd for $\text{C}_{22}\text{H}_{30}\text{O}_2$: C, 80.94, H, 9.26. Found: C, 80.92; H, 9.44.

3,5-Di-*tert*-butyl-4-(4-*tert*-butylphenoxy)phenol (26): 472 mg (67%) from 4-*tert*-butylphenol (**25**); colorless crystals from hexane; mp 139–140 °C; ^1H NMR δ 7.4–7.1 (m, 2 H), 7.0–6.7 (m, 2 H), 6.88 (s, 2 H), 4.97 (s, 1 H), 1.41 (s, 18 H), 1.31 (s, 9 H); ^{13}C NMR δ 156.3, 149.8, 148.4, 144.3, 137.2, 126.1, 116.6, 116.1, 34.5, 34.1, 31.5, 30.2; IR 3620 cm^{-1} . Anal. Calcd for $\text{C}_{24}\text{H}_{34}\text{O}_2$: C, 81.31; H, 9.67. Found: C, 81.02; H, 9.51.

3,5,5'-Tri-*tert*-butyl-4,2'-biphenol (27): 190 mg (27%) from **25**; colorless crystals from hexane; mp 136–137 °C; ^1H NMR δ 7.4–7.1 (m, 2 H), 7.24 (s, 2 H), 7.0–6.8 (m, 1 H), 5.30 (s, 1 H), 5.15 (s, 1 H), 1.47 (s, 18 H), 1.33 (s, 9 H); ^{13}C NMR δ 153.4, 150.1, 143.1, 136.7, 128.2, 128.1, 126.9, 125.7, 125.3, 114.8, 34.5, 34.1, 31.6, 30.3; IR 3620, 3540, 3300 cm^{-1} . Anal. Calcd for $\text{C}_{24}\text{H}_{34}\text{O}_2$: C, 81.31; H, 9.67. Found: C, 81.05; H, 9.86.

3,5-Di-*tert*-butyl-4-(4-methylphenoxy)phenol (29): 188 mg (30%) from 4-methylphenol (**28**); colorless crystals from hexane; mp 98–99 °C; ^1H NMR δ 7.2–7.0 (m, 2 H), 6.9–6.6 (m, 2 H), 6.86 (s, 2 H), 4.95 (s, 1 H), 2.30 (s, 3 H), 1.41 (s, 18 H); ^{13}C NMR δ 156.2, 149.6, 148.9, 137.2, 131.2, 129.8, 117.1, 116.1, 34.5, 30.2, 20.6; IR 3615 cm^{-1} . Anal. Calcd for $\text{C}_{21}\text{H}_{28}\text{O}_2$: C, 80.73; H, 9.03. Found: C, 80.77; H, 9.00.

3,5-Di-*tert*-butyl-5'-methyl-4,2'-biphenol (30): 245 mg (39%) from **28**; colorless crystals from hexane; mp 50–54 °C; ^1H NMR δ 7.22 (s, 2 H), 7.1–6.8 (m, 3 H), 5.29 (s, 1 H), 5.14 (s, 1 H), 2.31 (s, 3 H), 1.47 (s, 18 H); ^{13}C NMR δ 153.4, 150.2, 136.7, 130.5, 129.5, 128.8, 128.5, 127.8, 125.5, 115.1, 34.5, 30.3, 20.5; IR 3620, 3520, 3300 cm^{-1} . Anal. Calcd for $\text{C}_{21}\text{H}_{28}\text{O}_2$: C, 80.73; H, 9.03. Found: C, 80.66; H, 9.15.

3,5-Di-*tert*-butyl-4-(3,5-di-*tert*-butylphenoxy)phenol (32): 638 mg (78%) from 3,5-di-*tert*-butylphenol (**31**); colorless crystals from hexane; mp 119.5–121 °C (lit.⁷ mp 112–114 °C); ^1H NMR δ 7.09 (t, $J = 1.7$ Hz, 1 H), 6.89 (s, 2 H), 6.82 (d, $J = 1.7$ Hz, 2 H), 4.93 (s, 1 H), 1.41 (s, 18 H), 1.29 (s, 18 H); ^{13}C NMR δ 157.3, 152.1, 149.2, 148.8, 137.1, 116.0, 115.6, 111.8, 34.9, 34.5, 31.4, 30.2; IR 3620 cm^{-1} .

3,5-Di-*tert*-butyl-4-(3,5-dimethylphenoxy)phenol (34): 127 mg (19%) from 3,5-dimethylphenol (**33**); colorless crystals from hexane; mp 54–55 °C; ^1H NMR δ 6.87 (s, 2 H), 6.65 (s, 1 H), 6.56 (s, 2 H), 4.97 (s, 1 H), 2.26 (s, 6 H), 1.41 (s, 18 H); ^{13}C NMR δ 158.5, 149.7, 148.5, 139.1, 137.2, 123.5, 116.4, 114.7, 34.5, 30.2, 21.3; IR 3620 cm^{-1} . Anal. Calcd for $\text{C}_{22}\text{H}_{30}\text{O}_2$: C, 80.93; H, 9.26. Found: C, 80.96; H, 9.16.

3,5-Di-*tert*-butyl-2',6'-dimethyl-4,4'-biphenol (35) was obtained as a mixture with **33** (starting phenol) upon chromatography. A solution of the mixture in diisopropyl ether was shaken with aqueous NaOH. The organic layer was washed with water, dried, and evaporated to leave **35** (152 mg, 23%). Colorless crystals from diisopropyl ether/hexane: mp 214–240 °C; ^1H NMR δ 6.88 (s, 2 H), 6.58 (s, 2 H), 5.11 (s, 1 H), 4.63 (s, 1 H), 2.01 (s, 6 H), 1.44 (s, 18 H); ^{13}C NMR δ 153.6, 152.0, 138.1, 135.5, 131.2, 125.9, 113.8, 34.4, 30.5, 21.1; IR 3620, 3585, 3325 cm^{-1} . Anal. Calcd for $\text{C}_{22}\text{H}_{30}\text{O}_2$: C, 80.93; H, 9.26. Found: C, 80.73; H, 9.48.

3,5-Di-*tert*-butyl-4,6'-dimethyl-4,2'-biphenol (36): 292 mg (45%) from **33**; colorless crystals from hexane; mp 171–172 °C; ^1H NMR δ 7.04 (s, 2 H), 6.68 (s, 2 H), 5.28 (s, 1 H), 4.92 (s, 1 H), 2.31 (s, 3 H), 2.05 (s, 3 H), 1.45 (s, 18 H); ^{13}C NMR δ 153.4, 152.9, 137.9, 137.1, 136.8, 126.7, 125.9, 125.5, 122.5, 112.8, 34.5, 30.3, 21.2, 20.4; IR 3620, 3520, 3300 cm^{-1} . Anal. Calcd for $\text{C}_{22}\text{H}_{30}\text{O}_2$: C, 80.93; H, 9.26. Found: C, 80.83; H, 9.43.

3,5-Di-*tert*-butyl-4-(2,4,6-trimethylphenoxy)phenol (38): 236 mg (35%) from 2,4,6-trimethylphenol (**37**); colorless crystals from hexane; mp 104–105 °C; ^1H NMR δ 6.85 (s, 2 H), 6.57 (s, 2 H), 4.71 (s, 1 H), 2.28 (s, 3 H), 2.08 (s, 6 H), 1.36 (s, 18 H); ^{13}C NMR δ 150.8, 149.1, 147.5, 137.0, 133.5, 130.9, 129.2, 110.8, 34.5, 30.2, 20.8, 16.4; IR 3625 cm^{-1} . Anal. Calcd for $\text{C}_{23}\text{H}_{32}\text{O}_2$: C, 81.13; H, 9.47. Found: C, 80.98; H, 9.51.

3,5-Di-*tert*-butyl-3',5'-dimethoxy-4,4'-biphenol (40): 156 mg (22%) from **39**; light yellow crystals from diisopropyl ether, identical with an authentic sample (^1H NMR, IR, and TLC)

kindly provided by Dr. Nishino; mp 145.5–147 °C (lit.^{6,13} mp 201–201.5 °C). ^{13}C NMR δ 153.0, 147.0, 136.1, 134.0, 133.8, 132.9, 123.7, 104.2, 56.4, 34.4, 30.3.

3,5-Di-*tert*-butyl-2',4'-dimethoxy-4,3'-biphenol (41): 282 mg (39%) from **39**; light yellow oil; ^1H NMR δ 7.36 (s, 2 H), 6.83 (AB, $J = 8.6$ Hz, 1 H), 6.69 (AB, $J = 8.6$ Hz, 1 H), 5.75 (s, 1 H), 5.19 (s, 1 H), 3.89 (s, 3 H), 3.60 (s, 3 H), 1.47 (s, 18 H); ^{13}C NMR δ 152.7, 146.4, 144.5, 138.6, 135.4, 128.9, 128.6, 125.4, 120.1, 106.8, 60.2, 56.2, 34.4, 30.4; IR 3620, 3520 cm^{-1} ; HRMS calcd for $\text{C}_{22}\text{H}_{30}\text{O}_4$ 358.2145, found 358.2147.

3,5,3',5'-Tetra-*tert*-butyl-4,4'-diphenone (7b): 36 mg (9%) from the reaction of **39**; reddish brown crystals from benzene, identical with an authentic sample¹⁴ (^1H NMR and TLC); mp 246–248 °C (lit.¹⁴ mp 240–241 °C).

3,5-Di-*tert*-butyl-4-(4-chlorophenoxy)phenol (44): 379 mg (57%) from 4-chlorophenol (**43**); colorless crystals from hexane; mp 82.5–83.5 °C; ^1H NMR δ 7.3–7.1 (m, 2 H), 6.9–6.7 (m, 2 H), 6.86 (s, 2 H), 5.01 (s, 1 H), 1.41 (s, 18 H); ^{13}C NMR δ 157.3, 150.1, 148.2, 137.5, 129.2, 126.7, 118.2, 116.4, 34.5, 30.2; IR 3615 cm^{-1} . Anal. Calcd for $\text{C}_{20}\text{H}_{25}\text{O}_2\text{Cl}$: C, 72.17; H, 7.57; Cl, 10.65. Found: C, 72.30; H, 7.73; Cl, 10.45.

3,5-Di-*tert*-butyl-5'-chloro-4,2'-biphenol (45): 152 mg (23%) from **43**; colorless crystals from hexane; mp 107–108 °C; ^1H NMR δ 7.3–7.1 (m, 2 H), 7.19 (s, 2 H), 7.0–6.8 (m, 1 H), 5.34 (s, 1 H), 5.27 (s, 1 H), 1.46 (s, 18 H); ^{13}C NMR δ 153.9, 151.1, 137.0, 130.3, 129.6, 128.1, 126.4, 125.4, 125.1, 116.6, 34.5, 30.2; IR 3620, 3530, 3300 cm^{-1} . Calcd for $\text{C}_{20}\text{H}_{25}\text{O}_2\text{Cl}$: C, 72.17; H, 7.57; Cl, 10.65. Found: C, 72.04; H, 7.62; Cl, 10.72.

3,5-Di-*tert*-butyl-4-(4-acetylphenoxy)phenol (47): 158 mg (23%) from 4-acetylphenol (**46**); colorless crystals from diisopropyl ether; mp 128–130 °C; ^1H NMR δ 8.0–7.8 (m, 2 H), 7.0–6.8 (m, 2 H), 6.89 (s, 2 H), 5.09 (s, 1 H), 2.55 (s, 3 H), 1.43 (s, 18 H); ^{13}C NMR δ 196.4, 163.0, 150.6, 147.1, 137.7, 131.0, 130.4, 117.0, 116.0, 34.5, 30.2, 26.3; IR 3620, 1673 cm^{-1} . Anal. Calcd for $\text{C}_{22}\text{H}_{28}\text{O}_3$: C, 77.61; H, 8.29. Found: C, 77.51; H, 8.47.

3,5-Di-*tert*-butyl-5'-acetyl-4,2'-biphenol (48): 121 mg (18%) from **46**; colorless crystals from MeOH/hexane; mp 169–170 °C; ^1H NMR δ 8.0–7.8 (m, 2 H), 7.22 (s, 2 H), 7.1–6.9 (m, 1 H), 5.98 (s, 1 H), 5.37 (s, 1 H), 2.57 (s, 3 H), 1.47 (s, 18 H); ^{13}C NMR δ 196.8, 157.0, 153.9, 137.1, 131.0, 130.2, 129.4, 129.0, 126.5, 125.6, 115.3, 34.5, 30.2, 26.3; IR 3620, 3515, 3250, 1668 cm^{-1} . Anal. Calcd for $\text{C}_{22}\text{H}_{28}\text{O}_3$: C, 77.61; H, 8.29. Found: C, 77.53; H, 8.43.

3,5-Di-*tert*-butyl-4-(4-nitrophenoxy)phenol (50): 217 mg (32%) from 4-nitrophenol (**49**); light yellow crystals from hexane; mp 131–132 °C; ^1H NMR δ 8.2–8.0 (m, 2 H), 7.0–6.8 (m, 2 H), 6.90 (s, 2 H), 5.15 (s, 1 H), 1.44 (s, 18 H); ^{13}C NMR δ 164.2, 151.0, 146.6, 141.9, 137.9, 125.7, 117.1, 116.0, 34.5, 30.1; IR 3615 cm^{-1} . Anal. Calcd for $\text{C}_{20}\text{H}_{25}\text{O}_4\text{N}$: C, 69.95; H, 7.34; N, 4.08. Found: C, 69.88; H, 7.31; N, 3.79.

3,5-Di-*tert*-butyl-5'-nitro-4,2'-biphenol (51): 28 mg (4%) from **49**; light yellow crystals from hexane; mp 135–138 °C; ^1H NMR δ 8.2–8.0 (m, 2 H), 7.20 (s, 2 H), 7.1–6.9 (m, 1 H), 6.00 (s, 1 H), 5.43 (s, 1 H), 1.48 (s, 18 H); ^{13}C NMR δ 158.1, 154.4, 141.4, 137.4, 129.5, 126.0, 125.4, 125.1, 124.5, 115.7, 34.5, 30.2; IR 3620, 3515, 3200 cm^{-1} . Anal. Calcd for $\text{C}_{20}\text{H}_{25}\text{O}_4\text{N}$: C, 69.95; H, 7.34; N, 4.08. Found: C, 70.00; H, 7.33; N, 4.13.

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(13) Dr. Nishino corrected the melting point to 148.5–149.0 °C (private communication)

(14) Omura, K. *J. Org. Chem.* **1984**, *49*, 3046.