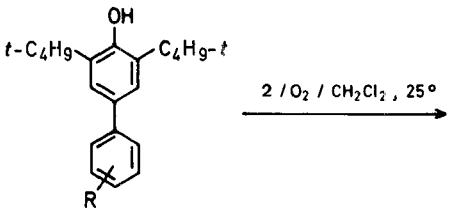
Synthesis of 4-Aryl-2,6-di-*t*-butyl-6-hydroperoxy-1-oxo-2,4-cyclohexadienes and their Conversion to the Corresponding *o*-Benzoquinones

Akira NISHINAGA*, Kanji NISHIZAWA, Haruo TOMITA, Teruo MATSUURA

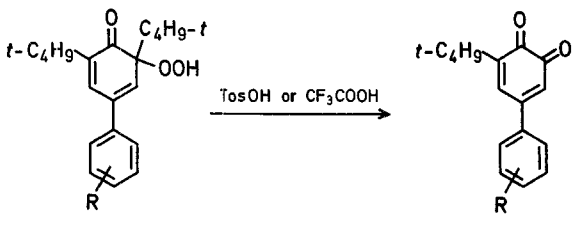
Department of Synthetic Chemistry, Faculty of Engineering, Kyoto University, Kyoto, Japan

Recently, we reported that the *o*-hydroperoxylation of 2,6-di-*t*-butyl-4-(4-methoxyphenyl)-phenol (**1a**) by base-catalyzed oxygenation affording 2,6-di-t-butyl-6-hydroperoxy-4-(4-methoxyphenyl)-1-oxo-2,4-cyclohexadiene (**3a**)[1]. We wish to report that the similar type of hydroperoxides (**3**) are easily synthesized by the oxygenation of phenols **1** using the complex Co (salpr)[2] (**2**) in dichloromethane at room temperature. The hydroperoxides **3** are quantitatively converted by acid catalysis to the corresponding *o*-benzoquinones (**4**).

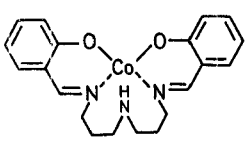
Equimolar amounts of the phenol **1** and Co(salpr) are dissolved in dichloromethane and oxygen is bubbled through the solution for about 2 h. The reaction mixture is filtered through a short column of silica gel to remove the cobalt complex. The filtrate is evaporated. The residue is triturated with petroleum ether to give the hydroperoxide **3** (Table 1). The same hydroperoxides are also obtained when oxygen is bubbled through a solution of **1** in a mixture of *t*-butanol and petroleum ether containing potassium *t*-butoxide at −20° for 2 h, the reaction mixture acidified with aqueous ammonium chloride solution, and subsequent evaporation of the solvent. Upon treating **3** with *p*-toluenesulfonic acid or trifluoroacetic acid in dichloromethane and filtration of the reaction mixture through a short column of silica gel followed by evaporation of the solvent, the corresponding *o*-benzoquinones **4** are obtained in crystalline forms (Table 2).



1



3 **4**



2 Co(salpr)

The *o*-benzoquinones **4** are also obtained by the direct acid treatment of the oxygenation reaction mixture with Co(salpr). No substituent effect is observed for the oxygenation and

Table 1. Hydroperoxides **3** from the Oxygenation of Phenols **1** with Co(salpr) (**2**)

Compound	R	Yield [%]	m.p.	Molecular formula[a]	^{1}H-N.M.R. ($CDCl_3$) δ [ppm] t-C_4H_9	t-C_4H_9	CH_3	C=CH[b]	C=CH[b]	Ar	OOH	U.V. (cyclohexane)[c] λ_{max} [nm] (ε)
3a	4-H_3CO	80	99–101°[d]	—	1.03	1.28	3.83	6.60	7.06	6.7–7.6	9.00	325 (sh, 1400)
3b	3-H_3CO	83	80–82°	$C_{21}H_{28}O_4$ (344.5)	1.03	1.28	3.86	6.62	6.93	6.9–7.4	8.67	328 (sh, 1500)
3c	2-H_3CO	76	100–102°	$C_{21}H_{28}O_4$ (344.5)	1.04	1.27	3.80	6.45	6.84	6.8–7.4	8.63	323 (sh, 1700)
3d	4-H_3C	67	105–107°	$C_{21}H_{28}O_3$ (328.5)	1.05	1.29	2.39	6.63	7.02	7.5	8.82	332 (1500)
3e	3-H_3C	62	81–83°	$C_{21}H_{28}O_3$ (328.5)	1.03	1.28	2.22	6.63	7.02	7.25	9.06	336 (1400)
3f	2-H_3C	70	111–113°	$C_{21}H_{28}O_3$ (328.5)	1.06	1.26	2.37	6.38	6.69	7.22	8.51	324 (2200)
3g	H	72	101–103°	$C_{20}H_{26}O_3$ (314.3)	1.03	1.29	—	6.04	7.02	7.4	8.96	328 (2100)
3h	4-Cl	68	105–107	$C_{20}H_{25}ClO_3$ (348.9)	1.03	1.26	—	6.65	6.95	7.2–7.4	8.50	328 (2000)
3i	2,4,6-tri-H_3C	84	110–111°	$C_{23}H_{32}O_3$ (356.5)	1.01	1.27	2.17 2.32	6.24	6.47	6.92	8.37	320 (2200)

[a] All compounds except **3a** are new and gave satisfactory microanalyses (C ±0.4%, H ±0.2%), analyses were carried out by the Laboratory of Organic Elemental Microanalysis, Faculty of Pharmaceutical Sciences, Kyoto University.
[c] All products gave bands at $\nu = 3360$ (OOH) and $\nu = 1660\,cm^{-1}$ (C=O) in the I.R. spectra.
[d] Lit.[1], m.p. 99–101°.

Table 2. *o*-Benzoquinones **4** from Hydroperoxides **3**

Compound	Yield [%]	m.p.	Molecular formula[a]	^{1}H-N.M.R. ($CDCl_3$) δ [ppm] t-C_4H_9	CH_3	4-H[b]	6-H[b]	Ar	U.V. (cyclohexane)[c] λ_{max}, [nm] (ε)
4a	100	140–142°	$C_{17}H_{18}O_3$ (270.3)	1.33	3.87	7.20	6.47	6.9–7.7	318 s (5500), 344 (8900), 359 s (7300), 425 (3800)
4b	100	115–116°	$C_{17}H_{18}O_3$ (270.3)	1.33	3.84	7.13	6.48	6.8–7.6	316 (3800), 379 (3000), 408 (2600)
4c	100	114–116°	$C_{17}H_{18}O_3$ (270.3)	1.30	3.91	7.05	6.45	6.8–7.6	314 (3700), 357 (4500), 365 (4400), 404 (2900)
4d	100	139–141°	$C_{17}H_{18}O_2$ (254.3)	1.33	2.43	7.25	6.56	7.2–7.7	327 (9400), 340 s (6500), 412 (2800)
4e	100	115–116°	$C_{17}H_{18}O_2$ (254.3)	1.33	2.44	7.22	6.53	7.39	318 (6300), 327 s (5700), 406 (2100)
4f	100	86–88°	$C_{17}H_{18}O_2$ (254.3)	1.27	2.37	6.84	6.29	7.32	318 (4200), 330 s (3900), 344 (2800), 400 (2100)
4g	100	126–127°[d]	—	1.36	—	7.13	6.56	7.53	317 (8200), 324 (6300), 403 (2500)
4h	100	122–123°	$C_{16}H_{15}ClO_2$ (274.8)	1.36	—	7.18	6.53	7.51	321 (8900), 405 (2500)
4i	100	94–96°	$C_{19}H_{22}O_2$ (282.4)	1.29	2.24 2.33	6.63	6.21	6.97	363 (2800), 400 (1700)

[a] All compounds except **4g** are new and gave satisfactory microanalyses (C ±0.3%, H ±0.2%).
[b] A pair of doublets, $J = 2.3$ Hz.
[c] All products gave bands at $\nu = 1690$ (C=O) and $\nu = 1660\,cm^{-1}$ (C=O) in the I.R. spectra.
[d] Lit.[5], m.p. 116–118°.

acid-catalyzed decomposition of **3**. Other solvents such as tetrahydrofuran and *t*-butanol can also be used in the synthesis of **3**.

It has been known that the catalytic oxygenation of 4-alkyl-2,6-di-*t*-butylphenols to give the corresponding *p*-quinols takes place when Co(salpr) is used in methanol[3]. The corresponding *o*-quinols obtained from the reduction of **3** are very susceptible to de-*t*-butylation to give the corresponding catechol derivatives. Since catechols are very easily oxidized by catalytic oxygenation with Co(salpr) to give the corresponding *o*-benzoquinones, it was expected that the oxygenation of **1** with Co(salpr) in methanol might give **4**. However, the catalytic oxygenation in methanol gives a complicated reaction mixture containing **4**. The oxygenation of **1** with cobalt complexes is strongly dependent on the ligand of the complexes. Thus, square-planer cobalt Schiff base complexes give rise to the predominant formation of one-electron transfer oxidation products of **1** in addition to **4**.

Oxidation of 2,6-Di-*t*-butyl-4-(substituted-phenyl)-phenols 1:
A solution of **1** (1 mmol) and Co(salpr) (**2**; 1 mmol) in dichloro-

methane (10 ml) was bubbled with oxygen for 2 h at 25°. The reaction mixture was filtered through a column of silica gel (6 g) and eluted with the same solvent. The first fraction contained the starting phenol **1** and from the second fraction the hydroperoxide **3** was isolated in crystalline form after evaporation of the solvent. No other product was detected in the reaction mixture. Physical data are listed in Table 1.

Acid Treatment of 2,6-Di-*t*-butyl-6-hydroperoxy-1-oxo-4-(substituted-phenyl)-2,4-cyclohexadiene 3:

To a solution of **3** (1 mmol) in dichloromethane (10 ml) *p*-toluenesulfonic acid (0.1 g) was added and the resulting solution was allowed to stand at room temperature for 10–20 min. The reaction mixture was filtered through a column of silica gel (5 g) and eluted with the same solvent (10 ml). The eluent was evaporated to give **4** in crystalline form, which was then recrystallized from petroleum ether. Physical data of **4** are listed in Table 2.

Received: December 21, 1976

[1] A. Nishinaga, A. Rieker, *J. Am. Chem. Soc.* **98**, 4667 (1976).
[2] Co (salpr) (**2**) is bis[3-salicylideneaminopropyl]aminecobalt(II) and was obtained according to Lit.[4].
[3] A. Nishinaga, K. Watanabe, T. Matsuura, *Tetrahedron Lett.* **1974**, 1291.
[4] H. Bailes, M. Calvin, *J. Am. Chem. Soc.* **69**, 1889 (1947).
[5] E. Müller, F. Günther, A. Rieker, *Z. Naturforsch. [b]* **18**, 1002 (1963).