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OXYGENATION OF 2,6-DI-t-BUTYLPHENOLS BEARING ELECTRON-WITHDRAWING GROUP AT 4-POSITION MEDIATED BY Co(II)-SCHIFF BASE COMPLEX

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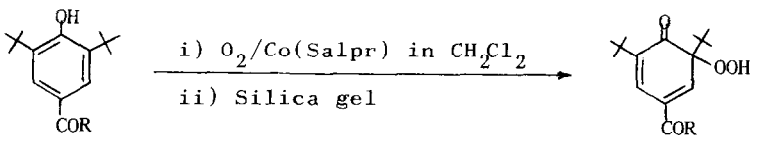
4-Acyl-2,6-di-t-butylphenols except 3,5-di-t-butyl-4-hydroxybenzaldehyde were oxygenated in the presence of Co(Salpr) exclusively at the ortho position to give the corresponding 3,5-di-t-butyl-6-hydroperoxy-2,4-cyclohexadienone derivatives in quantitative yield.

Co(Salpr) capable of binding dioxygen reversively to form a superoxo Co(III) complex is of particular interest in connection with biological oxygenations.[1] The complex has been shown to mediate oxygenation of 4-alkyl- and 4-aryl-2,6-di-t-butylphenols resulting in the regioselective formation of peroxyquinolato Co(III) complexes,[2] where the regioselectivity is the same as that observed in the base-catalyzed oxygenation of these phenols.[3] In the present paper, we wish to report that although 2,6-di-t-butylphenols with an electron-withdrawing group at the 4-position such as 4-acyl derivatives (**1**) and 2,6-di-t-butyl-4-cyanophenol (5) are unsusceptible to base-catalyzed oxygenation, Co(Salpr) can mediate the oxygenation of these phenols, where dioxygen is incorporated unexpectedly only at the ortho position.

The oxygenation of phenols **1**,[4] although the reaction was slower than the Co(Salpr)-mediated oxygenation of 4-alkyl- and 4-aryl-2,6-di-t-butylphenols, gave 4-acyl-2,6-di-t-butyl-6-hydroperoxy-2,4-cyclohexadienones (2) quantitatively, which were isolated as crystals in excellent yield (Table 1). Values of carbonyl absorption bands and olefinic proton signals of the product 2 listed in Table 1 are typical ones for 2,4-cyclohexadienones.[5,6] Chemical reactions of 2 also support the structure. That is, the reduction of 2c with dimethyl sulfide at room temperature gave 3-t-butyl-5-pyvaroylcatechol (3)[7] instantly



1 2

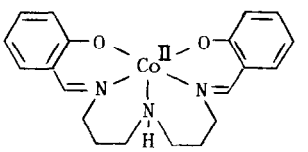
a; R = CH_3

b; R = $CH(CH_3)_2$

c; R = $C(CH_3)_3$

d; R = C_6H_5

e; R = OCH_3



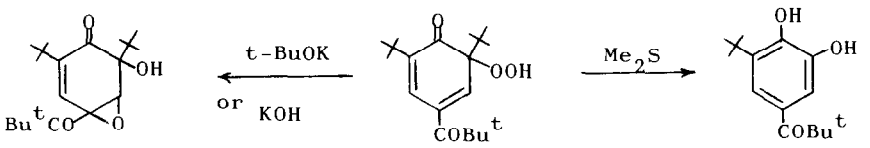
Co(Salpr)

Table 1. Formation and Physical Data of 4-Acyl-2,6-di-t-butyl-6-hydroperoxy-2,4-cyclohexadienones (2).[a]

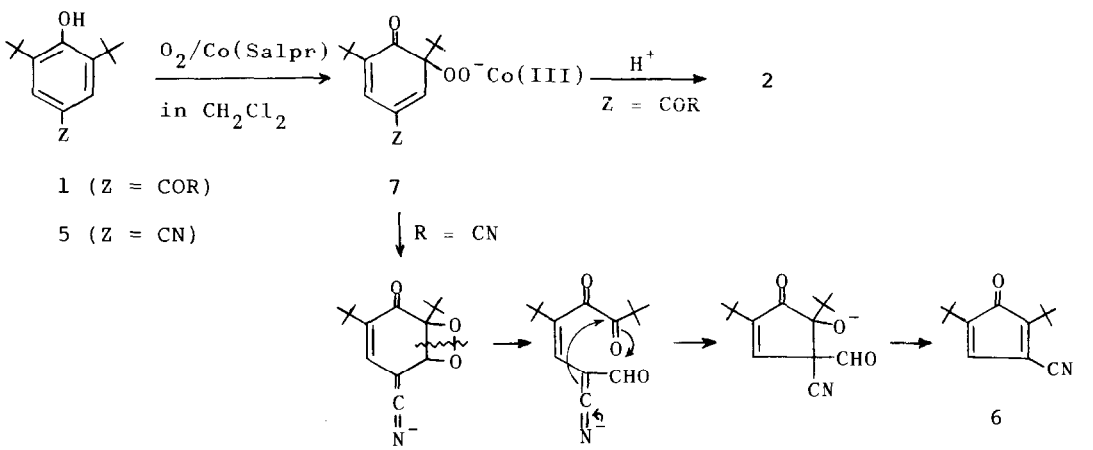
2	Yield[b] (%)	M.p.[c] (°C)	IR(Nujol), cm^{-1} OOH	IR(Nujol), cm^{-1} C=O	^1H NMR($CDCl_3$), δ ppm t-Bu	O=C-C=CH-C=CH[d]	OOH	R
2a	96	105	3370	1685, 1675	0.99, 1.26	7.30 7.38	9.35	2.43
2b	98	115	3370	1685, 1670	1.00, 1.25	7.31 7.38	9.26	1.18(d)[e] 1.22(d)[e] 3.38(m)[e]
2c	98	112	3370	1670	0.98, 1.23	7.01 7.13	9.08	1.33(s)
2d	92	107	3460	1680, 1665	1.00, 1.27	7.05 7.28	9.45	7.3-8.0(m)
2e	93	92	3450	1720, 1685	1.00, 1.27	7.17 7.48	8.72	3.87(s)

[a] Oxygen was bubbled through a solution of 1 (1 mmol) and Co(Salpr)(1.1 mmol) in CH_2Cl_2 (20 ml) at room temperature for 4.5 h. Products were separated by layer chromatography (silica gel/CH_2Cl_2). [b] Isolation yield based on conversion (60-70%). [c] Decomposition point. [d] A doublet of doublets, J = 2.4 Hz. [e] J = 7 Hz.

in quantitative yield, and the treatment of 2c with t-BuOK in t-BuOH or KOH in ethanol at room temperature gave 2,6-di-t-butyl-4-pyvaroyl-4,5-epoxy-6-hydroxy-2-cyclohexenone (4)[8] quantitatively. Compound 4 was quite stable against t-BuOK in a hot t-BuOH solution, in contrast with epoxy-o-quinols of type 4 obtained from 4-aryl-2,6-di-t-butylphenols, which give 3-aryl-2,5-di-t-butylcyclopentadienones under the conditions.[9] The stability of 4 against the base is due to the electron-withdrawing acyl group. The oxygenation of 5, on the other hand,



gave 3-cyano-2,5-di-t-butylcyclopentadienone (6) in 60% yield.[10] The formation of 6 can be considered analogous to the case of the oxygenation of 4-(N-alkylimino)methyl-2,6-di-t-butylphenols mediated by Co(Salpr),[11] where o-peroxyquinolato Co(III) complexes undergo an intramolecular decomposition involving a symmetric cleavage of the peroxy bond in a dioxetane intermediate. The present oxygenation may therefore be rationalized by the following scheme. Dioxygen is incorporated exclusively into the ortho position to give o-peroxyquinolato



Co(III) complex intermediates (7), among which the intermediate formed from 5 is unstable.

Interestingly, the regioselectivity of dioxygen incorporation in the present oxygenation is in contrast to that observed in the reaction of phenoxy radicals of 2a, 2e, and 5 with a superoxo Co(III) complex,[12] where radical coupling took place selectively at the para position of the phenoxy radicals giving rise to the corresponding p-hydroperoxy-2,5-cyclohexadienones. It is therefore evident that no such radical coupling mechanism is involved in the present oxy-

genation. A mechanism involving direct incorporation of dioxygen into a phenolato Co(III) complex intermediate may be acceptable as suggested for Co(Salpr)-mediated oxygenation of 4-alkyl- and 4-aryl-2,6-di-t-butylphenols.[13]

When oxygen was bubbled through a solution of 3,5-di-t-butyl-4-hydroxybenzaldehyde and Co(Salpr) in CH_2Cl_2, no oxygenation of the substrate took place and dark brown precipitates, $C_{35}H_{44}O_4N_3Co$ (m.p. >250 °C), were obtained in good yield. Since the precipitated complex gave the starting phenol quantitatively upon treatment with an acid, it should be a Co(III)(Salpr) complex coordinated with an anion of this substrate, probably an enolate form, although no structural information was available because this complex is sparingly soluble in usual solvents.

References and Notes

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4) Phenols 1a-d were readily prepared by acylation of 2,6-di-t-butylphenol with appropriate carboxylic acid in trifluoroacetic anhydride at room temperature. **1a**: 147-148 °C; **1b**: 145-147 °C; **1c**: 137-139 °C; **1d**: 132-134 °C.
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7) Compound **3**: colorless needles, m.p. 144-146 °C; ^{1}H NMR($CDCl_3$), δ 1.38(s, 9H), 1.42(s, 9H), 6.38(s,1H, OH), 7.54(d, 1H, J = 2.2 Hz), 7.60(d, 1H, J = 2.2 Hz), 7.97(s, 1H, OH).
8) Compound **4**: colorless needles, m.p. 151-152 °C; ^{1}H NMR($CDCl_3$), δ 0.98(s, 9H), 1.21(s, 9H), 1.23(s,9H), 3.80(d, 1H, J = 0.8 Hz), 6.76(d, 1H, J = 0.8 Hz), 4.03(s, 1H, OH).
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10) Compound **6**: orange needles, m.p. 61-62 °C; ^{1}H NMR($CDCl_3$), δ 1.16(s, 9H), 1.33(s, 9H), 6.48 (s, 1H); IR(Nujol), 2230(CN), 1735(CO) cm^{-1}; UV(C_6H_{12}), λ_{max} 421 nm (ε, 510).
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