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Base Catalyzed Oxygenation of 3,5-Di-*t*-butylpyrocatechol and Its Related Compounds

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Synopsis. The oxygenation of 3,5-di-*t*-butylcatechol (**1**) and its related compounds 3,5-di-*t*-butyl-*o*-benzoquinone (**2**), 4,6-di-*t*-butylpyrogallol (**3**), 2,4-di-*t*-butyl-5-oxo-2-hexenedioic acid (**4**), 2,4-di-*t*-butyl-4-(carboxyhydroxymethyl)-2-buten-4-olide (**5**), and 3,5-di-*t*-butyl-6-carboxy-2-pyrone (**6**) in DMF–Bu^{t}OK gave 2,4-di-*t*-butyl-4-hydroxy-2-buten-4-olide (**7b**). A possible mechanism and the relation between **4**, **5**, and **6**, the products in aqueous alkaline autoxidation of **1** and **3**, are discussed.

As a part of studies on model catalytic oxygenation for enzyme reactions, the base catalyzed oxygenation of 3,5-di-*t*-butylcatechol (**1**) and its related compounds has been investigated. The autoxidation of **1** in aqueous and methanolic NaOH solutions is known to give 2,4-di-*t*-butyl-5-oxo-2-hexenedioic acid (**4**) and 2,4-di-*t*-butyl-4-(carboxyhydroxymethyl)-2-buten-4-olide (**5**), respectively.[1,2] Compound **5** has also been obtained in the oxidation of 3,5-di-*t*-butyl-*o*-benzoqunone (**2**) with H_2O_2[2]. Campbell *et al.*[3] isolated **4** and 3,5-di-*t*-butyl-6-carboxy-2-pyrone (**6**) in the alkaline autoxidation of 4,6-di-*t*-butylpyrogallol (**3**). However, there has been no attempt to elucidate the relationship among these products sporadically obtained under different conditions.

We have found that the oxygenation of **1** in a DMF–Bu^{t}OK system newly gives 2,4-di-*t*-butyl-4-hydroxy-2-buten-4-olide (**7b**), and have made an attempt to correlate the products. When **1** was dissolved in DMF containing Bu^{t}OK under air, the solution assumed an intense blue color due to the formation of 3,5-di-*t*-butyl-*o*-benzosemiquinone (**8**) which was detected by ESR. The solution gradually turned brown with decay of the ESR signal. From the reaction mixture **7b**, the same product as that obtained in the photooxygenation of 4,6-di-*t*-butylresorcinol[4] was isolated. The structure of **7b** was confirmed by the fact that its acid catalyzed methanolysis gave 2,4-di-*t*-butyl-4-methoxy-2-buten-4-olide (**7c**), and also by examination of its spectral data (Table 1) and elemental analyses. Compound **7b** was also obtained in the oxygenation of **1** in MeOH containing MeONa (yield, 41%), and in that of **2**, **3**, **4**, **5**, and **6** in DMF–Bu^{t}OK. The results are summarized in Table 2. The air saturated solution of **3** in DMF–Bu^{t}OK showed the ESR spectrum of 4,6-di-*t*-butylpyrogallol anion radical (**9**), which rapidly disappeared by O_2 bubbling. The fact that **7b** was obtained in the oxygenation of **4**, **5**, and **6** in high yield suggests that they are correlated with each other to give an intermediary species in the oxygenation of **1**. Thus, the mechanistic pathway of the following scheme is suggested.

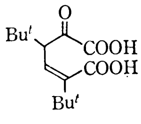
TABLE 1. THE NMR AND IR DATA OF **7** AND **5**

	NMR (τ_{CDCl_3}), ppm					IR (CO) cm^{-1}
	Bu^t	vinyl-H	-O-C-H	OH	OMe	
7a[a)]	9.05 8.75	3.05	5.48			1740
7b	8.98 8.80	3.26		5.87		1740
7c	9.00 8.70	3.34			6.84	1760
5[b)]	8.93 8.77	2.65	5.29			1755 1725

a) **7a** was prepared according to the method by Grinstead.[2] b) NMR; in CD_3OD.

TABLE 2. FORMATION OF **7b** IN THE OXYGENATION OF **1** AND ITS RELATED COMPOUNDS IN DMF–Bu^{t}OK

Substance	Bu^{t}OK/Subs. (mole ratio)	Reaction time (hr)	**7b** (%)
1	3	19	34
2	3	72	35
	3	40	36
3	3	12	16
	5	40	28
4	5	1	61
	5	17	76
5	6	24	82
6	6	3	47
	6	17	61



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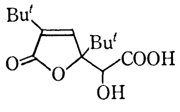

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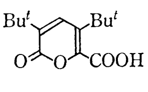

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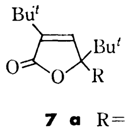
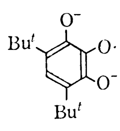


7 **a** R=H
b R=OH
c R=OMe



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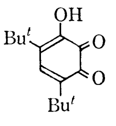

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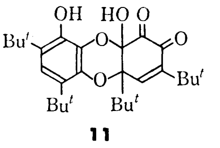

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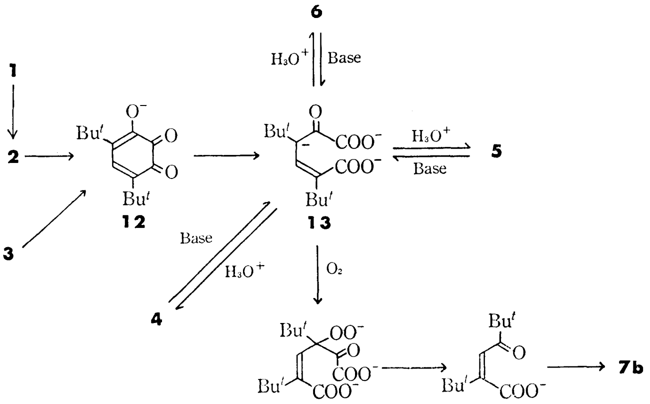
In aqueous alkaline oxygenation of **1** or **3**, one of **4**, **5**, or **6** is isolated depending on the conditions, while compounds **4**, **5**, and **6** are deprotonated to anion 2,4-di-*t*-butyl-5-oxo-2-hexen-4-idodioate (**13**) which would undergo further oxygenation to give **7b** in the DMF–Bu^{t}OK system. Hence, the poor yield of **7b** from **1** and **3** should be due to that of **13**.

As **5** is also obtained in high yield by the oxidation



of **2** with H_2O_2[2], it is quite reasonable to assume the transient formation of 3,5-di-*t*-butyl-6-oxido-*o*-benzoquinone (**12**) just before **13** in the scheme, although 3,5-di-*t*-butyl-6-hydroxy-*o*-benzoquinone (**10**), protonated compound of **12**, has not been synthesized so far. The oxidation of **3** with *p*-benzoquinone,5) Ag_2O,6) and $KIO_3$7) all gave a dimer, whose structure is believed to be **11**,7) but not **10**. The dimer, upon dissolving in DMF–Bu^{t}OK, also gave **9**, and then **7b** by bubbling of O_2. It is obscure whether the formation of **13** is caused by the oxidation of quinones **2** and **12** with H_2O_2 formed during the course of reaction or by the coupling of semiquinones **8** and **9** with O_2 or O_2^- in the oxygenation.

Experimental

Oxygenation of 1 in DMF-Bu^{t}OK. A solution of **1** (0.54 g), prepared according to the method of Schulze and Flaig,1) in DMF (15 ml) containing Bu^{t}OK (1 g) was bubbled with O_2 at room temperature for 19 hr. The resulting light brown reaction mixture was extracted with ether. The extract was washed with water, dried (Na_2SO_4), and evaporated. The silica gel tlc separation of the residue developed with a mixture of benzene-ether (3: 1 v/v) gave **7b**; colorless prisms; recrystallized from isooctane; mp 101.5—102 °C; yield, 0.18 g.

Found: C, 67.59; H, 9.45%. Calcd for $C_{12}H_{20}O_3$: C, 67.89; H, 9.50%.

Acid Catalyzed Methanolysis of 7b. A solution of **7b** (0.072 g) in MeOH (10 ml) containing a small amount of concd. H_2SO_4 was allowed to stand at room temperature for one week. The mixture was diluted with water and extracted with ether. The extract was washed (water), dried (Na_2SO_4), evaporated, and chromatographed on a silica gel column. The elution with a benzene–ether (5: 1 v/v) mixture gave **7c**; mp 60.5—61.5 °C; recrystallized from light petroleum; yield, 0.046 g (59%).

Found: C, 68.73; H, 9.75%. Calcd for $C_{13}H_{22}O_3$: C, 68.99; H, 9.80%.

Oxygenation of **2**, **3**, **4**, **5**, **6**, *and* **11** *in DMF-Bu^{t}OK.* Compounds **3**, **4**, **5**, **6**, and **11** were prepared according to the method of Schulze and Flaig,1) Grinstead,2) Campbell,4) and Critchlow *et al.*,7) respectively. The compounds were oxygenated and worked up as described above to give **7b**. The results are summarised in Table 2.

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