

Oxidation of Some 2,4,6-Trialkyl-substituted Phenols with Potassium Nitrosodisulfonate

Part II*

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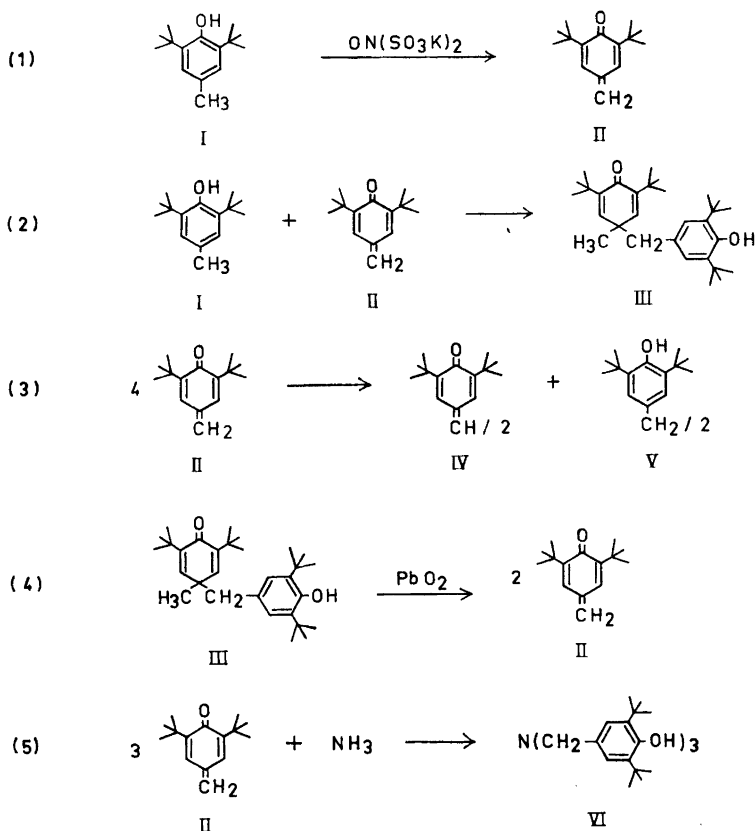
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In acetate-buffered solution 2,6-di-*tert*-butyl-4-methylphenol (I) reacts with nitrosodisulfonate to give as primary product 2,6-di-*tert*-butylquinonemethide (II). This substance then reacts further, either with the starting phenol forming the cyclohexadienone III or by dimerisation forming the diphenylethane IV and the stilbenequinone V. In the presence of ammonia the quinonemethide (II) gives the tribenzylamine VI.

The reaction of some 2,4,6-trialkyl-substituted phenols with nitrosodisulfonate was described in a previous communication.¹ In weakly acid solution 2,6-di-*tert*-butyl-4-methylphenol (I) on treatment with nitrosodisulfonate lost a butyl group and gave 3-*tert*-butyl-5-methyl-*o*-benzoquinone. However, the yield was low and apparently the reaction gave mainly *para*-oxidation products.

The reaction has now been carried out in weakly alkaline solution which minimises the formation of *o*-quinone.¹ In aqueous acetone solution buffered with sodium acetate, reaction of 2,6-di-*tert*-butyl-4-methylphenol with nitrosodisulfonate (mole ratio 1:2) gave after two days a mixture of starting material (I), 2,6-di-*tert*-butyl-4-(3,5-di-*tert*-butyl-4-hydroxybenzyl)-4-methyl-2,5-cyclohexadienone (III), 3,5,3',5'-tetra-*tert*-butylstilbenequinone (IV), and 4,4'-dihydroxy-2,6,2',6'-tetra-*tert*-butyldiphenylethane (V). Products III–V can be derived from an intermediate quinonemethide (II, eqn. 1) by addition of the starting phenol (eqn. 2) and by oxidoreductive dimerisation (eqn. 3), respectively. The latter reaction is well known and a mechanism has recently been suggested.² The stilbenequinone IV was formed in greater amount than the diphenylethane V, indicating that the latter had been partially oxidised to the stilbenequinone.

* Part I see Ref. 1.



The dienone (III) is not completely stable neither in crystalline form nor in solution. After standing for 14 days at room temperature, a benzene solution of the compound contained, in addition to large amounts of unchanged material, the phenol I, the stilbenequinone IV and the diphenylethane V. This indicates that the dienone III in solution undergoes carbon-carbon cleavage with the formation of phenol and quinonemethide, the latter giving the dimeric products IV and V. A similar reaction has been described by Coppinger.²

The ultraviolet spectrum of III (Fig. 1, curve 1) can be regarded as made up of contributions from both conjugated systems. The contribution of the phenolic part can be assumed to correspond to the spectrum of 2,6-di-*tert*-butyl-4-methylphenol (Fig. 1, curve 2). The dienone contribution can then be obtained as a difference spectrum by subtracting the absorption of the phenol from that of III. The resultant curve (Fig. 1, curve 3) is in good agreement with the spectra of similar dienones³ except for the maximum at 292 $m\mu$.

The dienone III readily gives the quinonemethide II on oxidation with lead dioxide in hexane (eqn. 4), the initial attack by the oxidant probably occurring on the hydroxyl group.

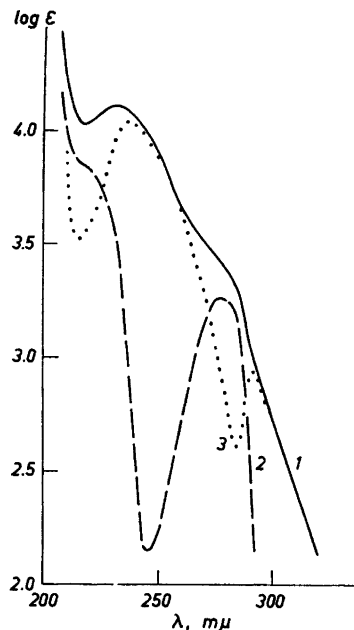


Fig. 1. Absorption spectra. (1) 2,6-Di-*tert*-butyl-4-(3,5-di-*tert*-butyl-4-hydroxybenzyl)-4-methyl-2,5-cyclohexadienone (III). (2) 2,6-Di-*tert*-butyl-4-methylphenol (I). (3) Difference spectrum (curve 1—curve 2). Solvent: 95 % ethanol.

The oxidation of 2,6-di-*tert*-butyl-4-methylphenol with nitrosodisulfonate was at first difficult to reproduce. It sometimes gave as a byproduct or even the main product a trimer which was later identified as tri-(4-hydroxy-3,5-di-*tert*-butylbenzyl)amine (VI) while at the same time the formation of the dienone was either partly or completely suppressed. It was found that the tribenzylamine was formed when the oxidant was contaminated with ammonia* and very small amounts would give amine formation. The tribenzylamine VI has been prepared earlier by treatment of an ethereal solution of the quinonemethide II with ammonia (eqn. 5).^{4,5}

These findings strongly support the view that the phenoxy radical arising in the oxidation of phenol I with nitrosodisulfonate¹ undergoes disproportionation or further oxidation to give the quinonemethide II (eqn. 1). Similar conversion of phenoxy radicals into quinonemethides has been reported previously.^{6,7} The formation of the dienone III (in the absence of ammonia) is then easily understood as being due to the addition of phenol I to the quinonemethide II (eqn. 2). In the light of the present results, it seems improbable that the dienone III is the result of a coupling between a phenoxy radical and a benzyl radical, as suggested in the preceding paper.¹

The formation of the dienone III seems to represent a previously unknown way of oxidative phenol coupling.

* Potassium nitrosodisulfonate is normally a relatively unstable compound. However, it has excellent stability if kept in a desiccator together with a beaker containing a few drops of conc. ammonia.

EXPERIMENTAL

Oxidation of 2,6-di-tert-butyl-4-methylphenol (I). A. In acetate buffer. A solution of I (2.20 g, 10 mmoles) in acetone (200 ml) was added to a mixture of potassium nitrosodisulfonate (5.4 g, 20 mmoles) in 0.2 N sodium acetate solution (125 ml). The mixture was stirred and after two days extracted with hexane. The yellow extract was chromatographed on a column of SiO₂. Elution with a mixture of hexane and methylene chloride (3:1) gave four fractions. The first fraction contained starting material (I), the second, 4,4'-dihydroxy-3,5,3',5'-tetra-tert-butylidiphenylethane (V), and the third and fourth, 3,5,3',5'-tetra-tert-butylstilbenequinone (IV) and the cyclohexadienone III. The two latter substances were incompletely separated. Recrystallisation from ethanol of the residue from the fourth fraction gave the cyclohexadienone III, plates, m.p. 115–117° (decomp.). [Found: C 82.05; H 10.44; MW (in benzene) 422. Calc. for C₃₀H₄₆O₂: C 82.13; H 10.58; MW 439.] UV spectrum: see Fig. 1. IR bands (CCl₄): 3650 (OH), 1662 and 1646 (dienone) cm⁻¹. The NMR spectrum (in CCl₄) consisted of singlets at δ 6.75 (aromatic ring H), 6.43 (vinyl H), 4.96 (OH), 2.69 (CH₂), 1.40 [C(CH₃)₃], and 1.17 [C(CH₃)₃ and CH₃] ppm relative to Si(CH₃)₄. Relative areas under these signals were in the ratio 2:2:1:2:18 (approximately): 21 (approximately). The yields of the products of the reaction were estimated from a thin layer chromatogram of the hexane extract (SiO₂, hexane/methylene chloride 3:1, developed with iodine) and comparison of the spots with those obtained from known amounts of the components. This gave 15 % starting material (I), 3 % diphenylethane V, 20 % stilbenequinone IV and 15 % cyclohexadienone III. Some unidentified products were also present.

B. In the presence of ammonia. A solution of the phenol I (1.10 g, 5 mmoles) in acetone (100 ml) was added to a solution of potassium nitrosodisulfonate (12.7 g, 10 mmoles) in water (50 ml) and conc. NH₃ (2 drops). The mixture was stirred for 4 h and allowed to stand for 2 days. The precipitate formed was filtered off and washed with water and ethanol. The insoluble material was the tribenzylamine VI (0.41 g, 37 %). The product was recrystallised from ligroin, needles, m.p. 230–240° (slow decomp.); literature value³ m.p. 231–232° [Found: C 80.49; H 10.29; N 2.26; MW (in benzene) 620. Calc. for C₄₅H₆₉NO₃: C 80.42; H 10.35; N 2.09; MW 672]. Extraction of the filtrate and the washings with hexane gave no further amounts of the tribenzylamine; only starting material and the stilbenequinone were detected in the extract by thin layer chromatography.

Acetate of VI. IV (64 mg) was dissolved in HClO₄ acetylation solution (5 ml).⁸ After 1 h the mixture was washed with water and NaHCO₃ solution and the organic phase was evaporated. The residue was recrystallised from ethanol, plates, m.p. 220° (Found: C 76.74; H 9.47. Calc. for C₅₁H₇₅NO₆: C 76.74; H 9.47).

Spontaneous decomposition of the cyclohexadienone III. A solution of III (0.1 g) in benzene (2 ml) was allowed to stand 14 days at room temperature. The originally colourless solution turned a clear yellow. This layer chromatography (SiO₂, CCl₄, I₂) showed the presence of cyclohexadiene III, the phenol I, the diphenylethane V and the stilbenequinone IV.

Oxidation of cyclohexadienone III with lead dioxide. When III (30 mg) in iso-octane (100 ml) was shaken with PbO₂ (1 g) for 30 min; the filtered solution was yellow and showed absorption values (λ_{\max} 285 m μ ; absorbance 1 cm 38) which were in good agreement with those expected (cf. Ref. 9) on the assumption that two moles of the quinone-methide II were formed for each mole of the dienone III. Evaporation of the solution gave a mixture of the stilbenequinone IV and the diphenylethane V.

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