Reaction of 3,6-di-*tert*-butyl-*o*-benzoquinone with dimedone. Functionalized derivatives of hindered *o*-quinones and catechols

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The reaction of 3,6-di-*tert*-butyl-*o*-benzoquinone with dimedone in the presence of a catalytic amount of Et_3N occurs as repeated 1,4-nucleophilic addition—oxidation and isomerization of a tricyclic quinone into quinomethane. The intermediate products were isolated and characterized. Semiquinone complexes of quinones were studied by ESR in solution.

Key words: synthesis, catechols, *o*-quinones, ESR.

The present work is a continuation of studies of the reactions of sterically hindered *o*-benzoquinones with nucleophilic reagents and describes the synthesis of novel polyfunctional *o*-quinones.

Formerly, the reactions of 3,6-di-*tert*-butyl-*o*-benzoquinone (**1**) with organometallic compounds[1,2] and with malonodinitrile as a typical CH-acid[3] were found to be of nucleophilic type. In the present work we studied for the first time the reaction of quinone **1** with β-diketones.

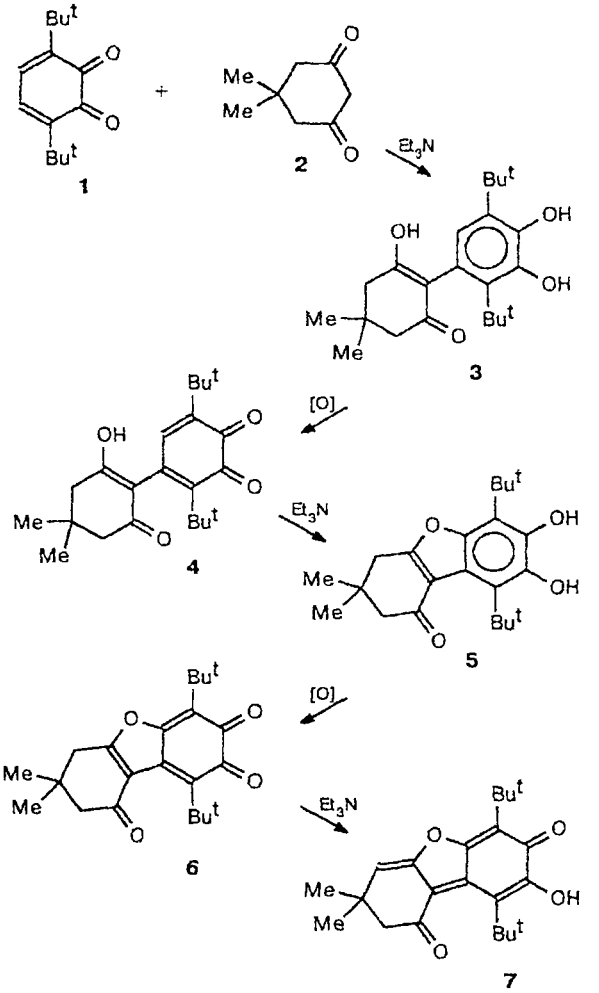
As expected, the reaction of quinone **1** with dimedone **2** in the presence of Et_3N as the catalyst results in products of 1,4-nucleophilic addition to the system of conjugated double bonds involving one of the carbonyl groups of the *o*-quinone.

When the reaction of equimolar amounts of compounds **1** and **2** was carried out in benzene in the presence of Et_3N, it was possible to isolate in a rather low yield the primary product of 1,4-addition, namely, pyrocatechol **3**. The latter was oxidized with potassium ferricyanide in an alkaline medium[4] into the corresponding *o*-quinone **4**.

When this reaction was carried out in MeOH, it did not stop at the stage of the formation of pyrocatechol **3**, but occurred in a more complicated way to give an array of products (Scheme 1), the sequence of the formation and accumulation of which could be monitored by TLC. As a result, conditions for the isolation of the particular compounds were selected.

It was found that quinone **4** is formed due to the oxidation of pyrocatechol **3** with the starting quinone in the presence of the amine, which is confirmed by the presence of 3,6-di-*tert*-butylpyrocatechol in the reaction mixture. The amount of the latter varies within 36—48% depending on the solvent and the duration of the reaction. We managed to stop the process at the step of formation of quinone **4** by performing the reaction in aqueous MeOH.

Scheme 1



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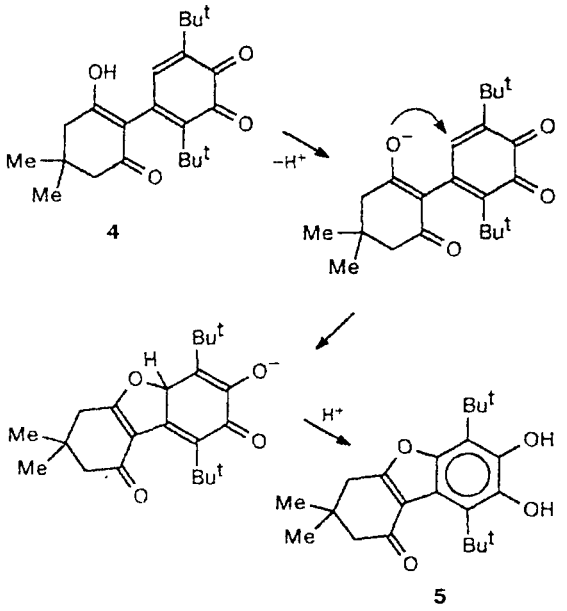
Pyrocatechol **5** was isolated when the reaction of compounds **1** and **2** was performed in MeOH. The formation of compound **5** from quinone **4** is due to intramolecular nucleophilic addition of the oxygen-centered anion of the "dimedone" moiety, which forms in the presence of a base, to the quinone moiety (Scheme 2).

Scheme 2



In turn, pyrocatechol **5**, like its analog **3**, undergoes oxidation into *o*-quinone **6**. The latter rearranges into the isomeric quinomethide **7** under the action of Et_3N. If the reaction is carried out for 5—6 h, quinomethide **7** is the only reaction product, no matter what solvent is used.

It is more convenient to perform the preparative synthesis of quinone **6** by the oxidation of hydroquinone **5** with $CuCl_2$ in the presence of Na_2CO_3.

The composition of the newly synthesized compounds **3**—**7** was confirmed by the data from elemental analyses. Their structures were established by spectroscopic methods.

The IR spectra of pyrocatechols **3** and **5** contain characteristic absorption bands of hydroxy groups at 3400 cm^{-1} (narrow) and 3200 cm^{-1} (broad) (the shapes of lines and the frequencies of stretching vibrations ν(OH) suggest the formation of intra- and intermolecular hydrogen bonds). Quinones **4** and **6** contained characteristic absorption bands in the region of 1680—1660 cm^{-1}.

The tentative division of the products into two groups, condensed and tricyclic, also follows from the IR spectra. The "dimedone" moiety of compounds **3** and **4**, in which the double bond of the carbonyl group participates in the exchange interactions of the trans-enol structure, is characterized by intense absorption in the region of 1630—1560 cm^{-1}. The stretching vibrations of the C=O bond correspond to narrow bands in the spectrum at lesser wavelengths.

In the IR spectrum of quinomethide **7**, the frequency of stretching vibrations of ν(C(7)=O) is decreased to 1585 cm^{-1}, and the ^1H NMR signal of the proton of the OH group at the *ortho* position to this carbonyl group is shifted downfield to δ 8.6. These data suggest the formation of an intramolecular hydrogen bond. The ^{13}C NMR spectrum confirms the structure of compound **7**: the region of δ 117—165 contains eight signals from the C atoms at the double bonds and two signals of the carbonyl C atoms at δ 179.5 (C(7)=O) and 196.9 (C(4)=O), while the high-field region contains signals of sp^3-hybridized C atoms.

o-Semiquinone complexes of *o*-quinones **4** and **6** were obtained and studied in solution by ESR.

The reaction of quinone **4** with $Mn_2(CO)_{10}$ gives a paramagnetic product, whose ESR spectrum has the following parameters: $A_i(^{55}Mn)$ = 0.73 mT, $A_i(H)$ = 0.32 mT. With time, the spectrum transforms into a sextet of triplets with a broadened central component, which corresponds to tetracarbonylmanganese semiquinone of cyclic quinone **6**: $A_i(H)$ = 0.40 mT is due to the hyperfine interaction of the unpaired electron with two protons at C(1), which at ~20 °C are in the state of rapid exchange on the ESR time scale; $A_i(^{55}Mn)$ = 0.69 mT.

The reaction of quinone **6** with $Mn_2(CO)_{10}$ gives a stable *o*-semiquinone derivative, which is stable in solution and whose ESR spectrum is identical with that described above (at ~20 °C). At 250 K, total broadening of the central components of the triplets occurs, and the spectrum transforms into a sextet of doublets of doublets on further decreasing the temperature. The coupling constants, $A_i(H)$ = 0.24 mT and $A_i(H)$ = 0.57 mT, suggest the nonequivalence of the protons at C(1). The mean lifetime of the conformer calculated from ESR data[5] changes from 2 to 0.46 ns within the temperature range studied (270—310 K) (Table 1). The kinetic parameters of conformational transformations of the cyclohexene moiety in the semiquinone derivative **6** are as follows: log A = 13.5, E_A = 5.9 kcal mol^{-1}. The correlation coefficient of the kinetic equation r = 0.998.

Experimental

IR spectra were recorded on a Specord M-80 spectrophotometer. UV spectra were obtained on a Specord M-40 instrument. NMR spectra were recorded on Tesla BS-567A (^1H, 100 MHz and ^{13}C, 25 MHz) and Gemini-300 (^1H, 300 MHz) spectrometers using HMDS as the internal standard. ESR spectra were recorded on a Bruker ER 200D-SRC spectrometer with a ER 4105DR double resonator, at 9.5 GHz working frequency. DPPH was used as the standard in the determination of the *g*-factor.

3,6-Di-*tert*-butyl-*o*-benzoquinone (1) was synthesized by a known procedure.[4]

3,6-Di-*tert*-butyl-4-(2-hydroxy-4,4-dimethyl-6-oxocyclohex-1-enyl)pyrocatechol (3). Et_3N (2—3 drops) was added to a solution of compound **1** (2.2 g) and dimedone **2** (1.40 g)

Table 1. Kinetic parameters of the conformational transformation of the cyclohexene cycle in the semiquinone derivative **6**

T/K	ΔH/G	τ_A/ns	log*k*
270	0.56	2.00	8.699
280	0.36	1.27	8.896
290	0.26	0.92	9.036
300	0.20	0.69	9.161
310	0.13	0.46	9.337

Note. $\Delta H = H - H_0$ (H is the width of the central line of the triplet in the ESR spectrum, H_0 = 0.23 G is line width with account of a correction for the Lorentz line shape), and τ_A is the average lifetime of the conformer.

in benzene (200 mL). The mixture turns reddish-brown. The course of the reaction was monitored by TLC (Silufol UV-254, heptane—ethyl acetate, 200 : 1). After the starting quinone had reacted completely, the mixture was neutralized with 30% HCl, washed with water until neutral pH, and dried with $MgSO_4$. The solution was concentrated and cooled, and the resulting precipitate was filtered off. The product was recrystallized from benzene to give white crystals, yield 16%, m.p. 195—196 °C. Found (%): C, 73.30; H, 8.72. $C_{22}H_{32}O_4$. Calculated (%): C, 73.33; H, 8.89. IR, ν/cm^{-1}: 1590 (C=O); 3200, 3540, 3560 (OH). ^{1}H NMR ($CDCl_3$), δ: 1.16 (s, 6 H, 2 Me); 1.36 (s, 9 H, Bu^t); 1.37 (s, 9 H, Bu^t); 2.32 (s, 2 H, 5'-CH_2); 2.40 (m, 2 H, 3'-CH_2, AB-system, ^2J = 14.6 Hz); 5.41 (s, 1 H, OH); 5.49 (s, 1 H, OH); 5.68 (s, 1 H, OH); 6.29 (s, 1 H, 5-H).

3,6-Di-*tert*-butyl-4-(2-hydroxy-4,4-dimethyl-6-oxocyclohex-1-enyl)-*o*-benzoquinone (4). *A.* Et_3N (2—3 drops) was added to a solution of compound **1** (2.2 g) and dimedone **2** (1.40 g) in MeOH (100 mL). After some amount of pyrocatechol **3** had formed in the reaction mixture (TLC), water (~50 mL) was gradually added dropwise over a period of 1 h. As a result, quinone **4** precipitated as a fine greenish-brown powder. The precipitate was filtered off. Yield 33%, m.p. 137—138 °C. Found (%): C, 73.66; H, 8.87. $C_{22}H_{30}O_4$. Calculated (%): C, 73.74; H, 8.38. IR, ν/cm^{-1}: 1600, 1660, 1685 (C=O); 3200 (OH). ^{1}H NMR (acetone-d_6), δ: 1.06 (s, 6 H, 2 Me); 1.08 (s, 9 H, Bu^t); 1.10 (s, 9 H, Bu^t); 2.30 (d, 2 H, CH_2); 2.60 (d, 2 H, CH_2); 6.38 (s, 1 H, 5-H).

B. A solution of pyrocatechol **3** (0.2 g) in ether was added with continuous stirring to a solution of $K_3[Fe(CN)_6]$ (9 g) and $NaHCO_3$ (5 g) in water (100 mL). The mixture was stirred for 1 h at ~20 °C. The aqueous layer was separated, neutralized with acetic acid, and extracted with toluene. The extract was concentrated to give crystals of quinone **4**.

5,8-Di-*tert*-butyl-6,7-dihydroxy-2,2-dimethyl-1,2,3,4-tetrahydrodibenzo[*b,d*]furan-4-one (5). Et_3N (2—3 drops) was added to a solution of compound **1** (2.2 g) and dimedone **2** (1.40 g) in MeOH (100 mL). After the formation of the product of oxidation of pyrocatechol **5** had begun in the system (TLC), the mixture was neutralized with acetic acid. The products were extracted with ether, and the extract was washed with water until neutral pH, dried with $MgSO_4$, and concentrated. The residue was dissolved in hexane, and the product was purified by column chromatography on Silochrome (with heptane—ethyl acetate, 100 : 1, as the eluent) and recrystallized from heptane to give yellow crystals, yield 24%, m.p. 280 °C. Found (%): C, 73.85; H, 8.56. $C_{22}H_{30}O_4$. Calculated (%): C, 73.74; H, 8.38. IR, ν/cm^{-1}: 1680 (C=O); 3200, 3430 (OH). ^{1}H NMR ($CDCl_3$), δ: 1.14 (s, 6 H, 2 Me); 1.60 (s, 18 H, 2 Bu^t); 2.47 (s, 2 H, 3-CH_2); 2.88 (s, 2 H, 1-CH_2); 5.66 (s, 1 H, OH); 6.41 (s, 1 H, OH).

5,8-Di-*tert*-butyl-2,2-dimethyl-1,2,3,4,6,7-hexahydrodibenzo[*b,d*]furan-4,6,7-trione (6). A solution of pyrocatechol **5** (0.5 g), $CuCl_2$ (0.3 g), and Na_2CO_3 (0.2 g) in 30 mL of a THF—MeOH mixture (50 : 1) was stirred for 40 min and then concentrated. The residue was crystallized from ether, and dark violet crystals were isolated, yield 86%, m.p. 146—148 °C. Found (%): C, 73.99; H, 8.00. $C_{22}H_{28}O_4$. Calculated (%): C, 74.16; H, 7.87. IR, ν/cm^{-1}: 1600, 1650, 1680 (C=O). ^{1}H NMR ($CDCl_3$), δ: 1.18 (s, 6 H, 2 Me); 1.32 (s, 9 H, Bu^t); 1.33 (s, 9 H, Bu^t); 2.43 (s, 2 H, 3-CH_2); 2.63 (s, 2 H, 1-CH_2). UV (heptane—Et_2O, 7 : 2), λ_{max}/nm: 270 (ε 6000), 490 (ε 1000), 590 (ε 150).

5,8-Di-*tert*-butyl-6-hydroxy-2,2-dimethyl-2,3,4,7-tetrahydrodibenzo[*b,d*]furan-4,7-dione (7). Et_3N (2—3 drops) was added to a solution of compound **1** (2.2 g) and dimedone **2** (1.40 g) in benzene (200 mL). After 5—6 h, the reddish-brown mixture was neutralized with AcOH, washed with water to a neutral pH, and dried with $MgSO_4$. The product was purified by column chromatography on Silochrome. The reddish-brown zone was extracted with a heptane—ethyl acetate mixture (100 : 1). The solvent was removed, and the product was crystallized from MeOH to give red crystals, yield 36%, m.p. 147 °C. Found (%): C, 74.30; H, 7.93. $C_{22}H_{28}O_4$. Calculated (%): C, 74.16; H, 7.87. IR, ν/cm^{-1}: 1585, 1700 (C=O); 3250 (OH). ^{1}H NMR ($CDCl_3$), δ: 1.28 (s, 6 H, 2 Me); 1.40 (s, 9 H, Bu^t); 1.44 (s, 9 H, Bu^t); 2.72 (s, 2 H, CH_2); 5.91 (s, 1 H, CH); 8.60 (s, 1 H, OH).

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References

1. G. A. Abakumov, V. K. Cherkasov, L. G. Abakumova, N. O. Druzhkov, V. I. Nevodchikov, Yu. A. Kurskii, and N. P. Makarenko, *Metalloorg. Khim.*, 1991, **4**, 925 [*Organomet. Chem. USSR*, 1991, **4** (Engl. Transl.)].
2. G. A. Abakumov, V. K. Cherkasov, L. G. Abakumova, V. I. Nevodchikov, N. O. Druzhkov, N. P. Makarenko, and Yu. A. Kursky, *J. Organomet. Chem.*, 1995, **491**, 127.
3. G. A. Abakumov, V. I. Nevodchikov, N. V. Zaitova, N. O. Druzhkov, L. G. Abakumova, Yu. A. Kurskii, and V. K. Cherkasov, *Izv. Akad. Nauk, Ser. Khim.*, 1997, 351 [*Russ. Chem. Bull.*, 1997, **46**, 337 (Engl. Transl.)].
4. V. A. Garnov, V. I. Nevodchikov, L. G. Abakumova, and V. K. Cherkasov, *Izv. Akad. Nauk SSSR, Ser. Khim.*, 1987, 1863 [*Bull. Acad. Sci. USSR, Div. Chem. Sci.*, 1987, **36**, 1728 (Engl. Transl.)].
5. J. Wertz and J. R. Bolton, *Electron Spin Resonance. Elementary Theory and Practical Applications*, McGraw-Hill, New York, 1972.

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