

SYNTHESIS AND PROPERTIES OF p-C₈-BRIDGED HYDROQUINONES AND p-BENZOQUINONES

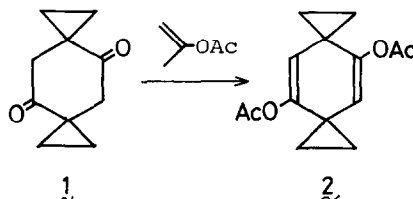
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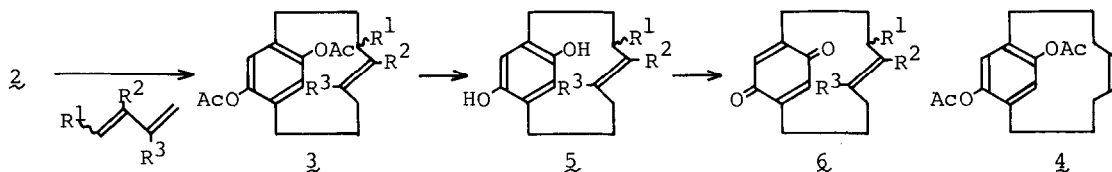
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Summary: The cycloaddition of the dispiro compound, 2, with a variety of 1,3-butadienes affords diacetates of p-C₈-bridged hydroquinones, which are led to the corresponding hydroquinones and p-benzoquinones.

Multifunctionalized cyclophanes are of much current interests. Recently, attentions have been focused on the donor-acceptor interaction between the two aromatic rings in the [m.n]cyclophanes.¹⁾ Various functionalized cyclophanes have also been employed as model compounds of enzymes exploiting the specific, well-defined stereochemical arrangement of the functional groups in them.²⁾ In order to develop these fascinating areas further, developments of the synthetic method of such cyclophanes are highly desirable. If our previously reported method³⁾ to prepare [3]paracyclophane derivatives can be extended to the functionalized starting compound, a number of functionalized cyclophanes, bridged with a relatively short-alkyl chain in particular, can be materialized easily. Such was indeed the case and we report the preparations of bridged hydroquinones and p-benzoquinones in the present paper.

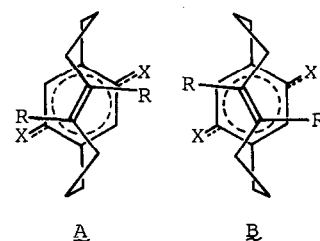
Treatment of the readily accessible diketone, 1,³⁾ with isopropenyl acetate in the presence of catalytic amount of TsOH afforded colorless, crystalline 4,9-diacetoxydispiro[2.2.2.2]deca-4,9-diene, 2, in 94% yield. When 2 and two equiv of 1,3-butadiene in benzene were heated at 170° for 7 h, two 1:1 addition products were obtained, for which the structures represented by 3a (66%) and 4 (11%) were assigned.⁴⁾ The reaction was general and a variety of substituted 1,3-butadienes underwent analogous cycloadditions with 2 giving 3 in 50-90% yields. The addition of unsubstituted or 2-substituted 1,3-butadiene to 2 produced single adduct possessing a trans-double bond on the bridge⁵⁾ whereas the reaction with 2,3-disubstituted diene furnished a mixture of two rotational isomers, 3^A and 3^B, which were separated and characterized.^{6,7)} Although the mechanism of the present cycloaddition reaction has not been studied in detail, it probably proceeds by way of the biradical intermediate resulting from the homolysis of the cyclopropane ring in 2 as has been proposed for the reaction of the parent dispiro compound.³⁾ The diacetates obtained were



Table 1. Yields (isolated) of **3**, **5**, and **6**.

R ¹	R ²	R ³	3	5	6
a. H	H	H	66 ¹⁾	87	81 ²⁾
b. cyclo-C ₃ H ₅	H	H	68 ³⁾	83	75 ²⁾
c. CO ₂ CH ₃	H	H	89 ⁴⁾		
d. H	CH ₃	H	65	90	-- ⁵⁾
e. H	CN	CN	A	37	76
		B	28	80	71 ²⁾
f. H	OEt	OEt	A	26	70
		B	26	78	-- ⁵⁾

1) Besides **3a**, **4** was obtained in 11% yield.
 2) Yield of **6** obtained from **3** without isolating **5**.
 3) Mixture of epimers (1:0.7). 4) Mixture of epimers (1:0.8). Yield by GLC. 5) The product, **6**, underwent a secondary reaction under the conditions.



hydrolyzed in alkaline aqueous EtOH in the usual way to give the corresponding hydroquinones, **5**, which were subsequently oxidized with FeCl₃ or Ce(NO₃)₄ · 2NH₄NO₃ to the p-benzoquinones, **6**. The results are summarized in Table 1.

The electronic spectra of **5** and 2,5-dimethylhydroquinone, **7**, are shown in Fig. 1. Bathochromic shift of 3-9 nm in the spectra of **5a** and **5f** compared to that of **7** may be attributable to the deformation of the aromatic ring in **5** from a planar configuration.⁹⁾ Of the two dicyano substituted derivatives, **5a** exhibits a strong extra absorption band at 361 nm (ε=3100) indicating the presence of a transannular electronic interaction.

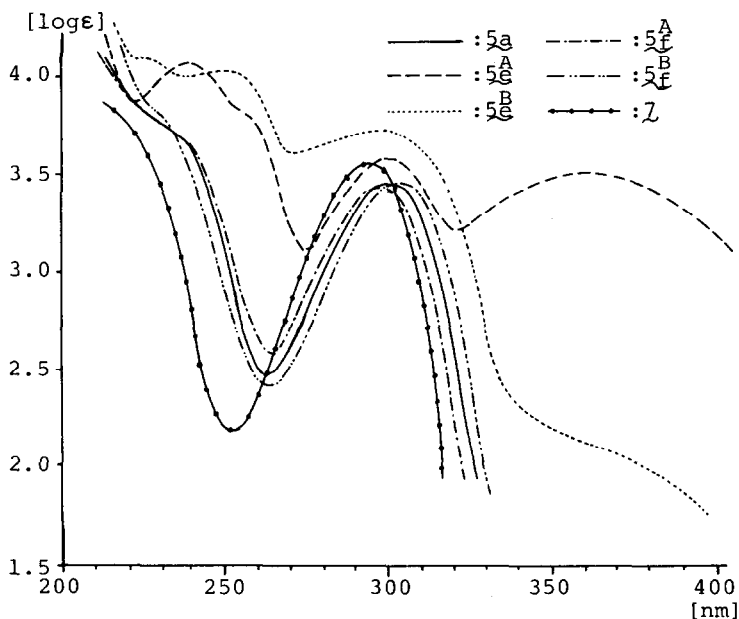


Fig. 1. The electronic spectra of **5** and **7** in EtOH. In striking contrast, **5b** showed only a shoulder of low intensity at

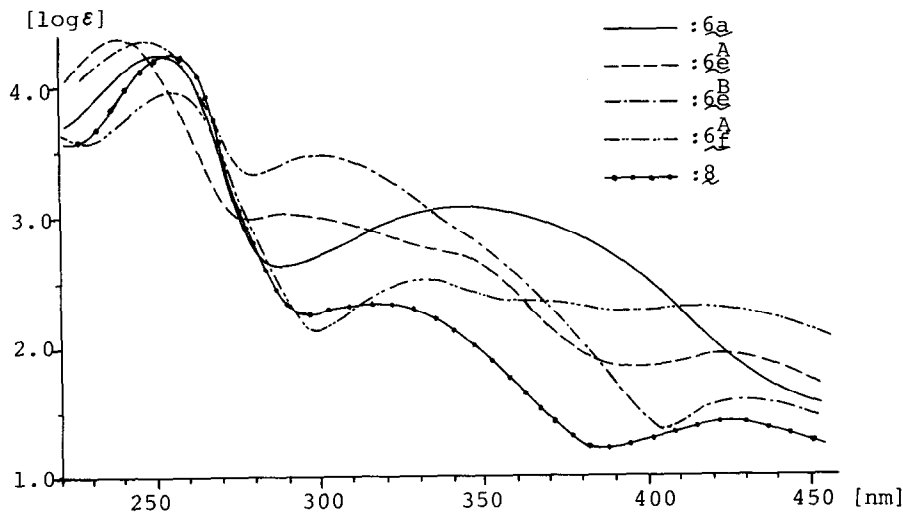


Fig. 2. The electronic spectra of $\underline{6}$ and $\underline{8}$ in EtOH.

the same region. Indeed the absorption intensity of $\underline{5e}^A$ at 361 nm is higher by a factor of about 20 than that of $\underline{5e}^B$. The clear-cut dependence of the absorption intensity on the donor-acceptor orientation in such a simple system is noteworthy.¹⁾

The C₈-bridged *p*-benzoquinones, $\underline{6}$, obtained by the oxidation of $\underline{5}$, were purified by sublimation under reduced pressure. The thermal instability of $\underline{6d}$ thwarted the isolation in an analytically pure state. The oxidation of $\underline{5f}^B$ led to a colorless product, in contrast with $\underline{5f}^A$ which gave $\underline{6f}^A$ in good yield. Even yellow-color development indicating the formation of *p*-benzoquinone was not observed during the oxidation of $\underline{5f}^B$. Analysis of the colorless product demonstrated that the *p*-benzoquinone, $\underline{6f}^B$, underwent a facile secondary reaction, which will be discussed in the accompanying report. The electronic spectra of $\underline{6}$ are shown in Fig. 2 together with that of 2,5-dimethyl-*p*-benzoquinone, $\underline{8}$. The transannular charge-transfer interaction in $\underline{6}$ is not so evident. Stronger absorptions at 350-450 nm in the spectra of $\underline{6a}$ and $\underline{6f}^A$ compared to the absorption at the same region in that of $\underline{8}$ may indicate the transannular electronic interaction in the former two compounds.¹⁰⁾ Although the diethoxy derivative, $\underline{6f}^A$, is tinted orange compared to yellow $\underline{6a}$, $\underline{6e}$, and $\underline{8}$, no notable extra absorption band is observed in long wavelength region of the spectrum of $\underline{6f}^A$, in marked contrast with the observation in $\underline{5e}^A$. It is inferred that the unsaturated bond in $\underline{6f}^A$ is not so electron-rich as expected because of the steric hindrance against the conjugation between the double bond and the lone pair electrons on the oxygens. For the effective conjugation between those groups, all the double bond, the oxygen, and the methylene carbon of the ethyl group are required to lie on the same plane.¹¹⁾ In such a conformation, however, the severe steric hindrance between the bridging methylenes and the ethyl groups results as depicted in

Fig. 3. Probably the ethyl groups are forced to twist away from the plane of the double bond, thus resulting in the diminished flow of the electron density from the oxygen to the double bond.

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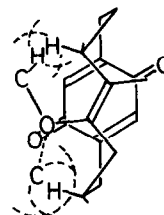


Fig. 3

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- 4) Satisfactory elemental analysis was obtained for each new compound.
3a: mp 129.5-130.5°; NMR(CDCl₃, 100 MHz), δ 1.2-3.0 (br m containing s at δ 2.3, 18H), 4.15 (m, 2H), 6.70 (s, 2H); Mass(70 eV), m/e(rel intensity) 302 (M⁺, 3), 260 (5), 218 (100), 200 (22), 136 (18); UV(EtOH), $\lambda_{max}(\epsilon)$ 225 (6100), 275 (710); IR(KBr), 1764 cm⁻¹.
4: mp 120.2-120.7°; NMR(CDCl₃, 100MHz), δ 1.4-3.0 (br m containing s at δ 2.3, 18H), 4.58 (br t, 2H), 6.80 (s, 2H); Mass(70 eV), m/e(rel intensity) 302 (M⁺, 4), 260 (4), 218 (100), 200 (46), 136 (31); UV(EtOH), $\lambda_{max}(\epsilon)$ 217^{sh} (17000), 282 (630); IR (KBr), 1764 cm⁻¹. Other new compounds also showed spectra (NMR, Mass, IR) compatible with the assigned structures.
- 5) Cycloadduct possessing a cis-double bond on the side chain was not isolated except for 4. Such products might be found in a few unidentified minor products invariably detected in the product mixtures.
- 6) The assignment was carried out primarily through the scrutiny of their NMR spectra. For example, in the spectrum of 3a, The aromatic proton signal appears at the higher field by 0.08 ppm whereas the acetoxy methyl proton signal appears at the lower field by 0.05 ppm, compared to those in the spectrum of 3b, reflecting the deshielding effect by the cyano groups.
- 7) The activation energy for the rotation of the double bond, 9 \rightleftharpoons 10, has been reported to be 13.4 \pm 0.7 kcal/mol.⁸⁾ The rotational barriers in 3a-d will not be much different from the above value and hence the interconversion will be facile at the ambient temperature when either of the olefinic carbons is bearing hydrogen. When both the olefinic carbons are substituted, however, the interconversion of the rotational isomers without rupturing the bridging carbon-carbon bond is almost impossible as molecular models show.
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