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ROLE OF ADDED DI-*T*-BUTYLNITROXIDE IN REACTIONS OF 1-IODOCYCLOHEXENES WITH POTASSIUM *T*-BUTOXIDE IN DIMETHYL SULFOXIDE: TRAPPING OF INTERMEDIATE DIRADICALS

A. T. Bottini* and L. J. Cabral
Department of Chemistry, University of California, Davis, California 95616
Vasu Dev
Department of Chemistry, California State Polytechnic University, Pomona, California 91768

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The reaction of 1-iodocyclohexene with *t*-BuOK:*t*-BuOH in DMSO at 65° gives a 10% yield of 1-*t*-butoxycyclohexene and a 32% yield of *trans*-tricyclo[6.4.0.0^{2,7}]2,12-dodecadiene **1** together with small amounts of C_8 hydrocarbons and 3 other C_{12} hydrocarbons isomeric with **1**.[1] Our further examination of this reaction has revealed that the C_{18} hydrocarbon **2**[2] is also formed in 25% yield. From study of the reactions of isotopically labeled 1-iodocyclohexenes,[1] it was concluded that the ether is formed in nearly equal amounts by addition of the elements of *t*-BuOH to the transitory intermediates 1,2-cyclohexadiene and cyclohexyne, and that **1** is formed by dimerization of the 1,2-cyclohexadiene formed directly by dehydroiodination of the iodide. When the course of the reaction of 1-iodocyclohexene with *t*-BuOK:*t*-BuOH in DMSO was followed closely by glpc up to 250°, it was observed that **2** appears in significant concentration only after an appreciable concentration of dimer **1** is reached, and then the concentration of **2** increases much more rapidly than that of **1**. This indicates that **2** is formed from **1** and 1,2-cyclohexadiene, possibly by a [4 + 2]cycloaddition to give an unstable cyclobutene, which undergoes electrocyclic ring opening to **2**.

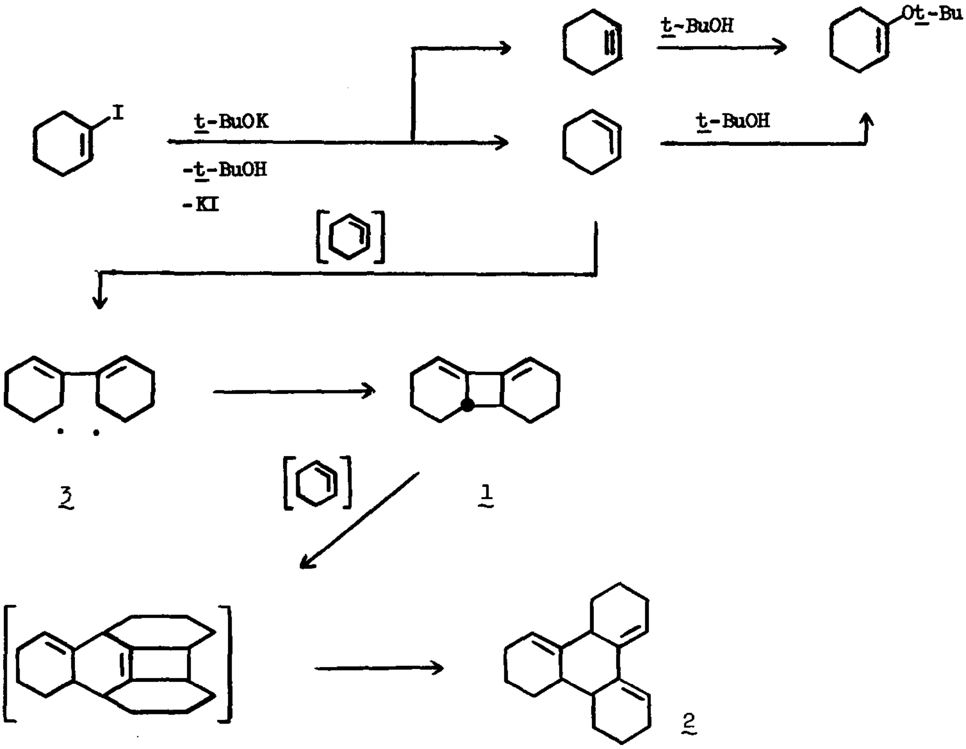
Compound **1** has also been prepared by reactions of the other 1-halocyclohexenes with *t*-BuOK,[1,3] by treatment of 1,6-dibromo-[4] or 1,6-dichlorocyclohexene[5,6] with magnesium, and by treatment of 6,6-dibromobicyclo[3.1.0]hexene with methyllithium.[7] From their study of the temperature dependence of the course of this last reaction, Moore and Moser concluded that formation of **1** from 1,2-cyclohexadiene occurs *via* the intermediacy of the *bis*-allylic diradical **3**.

The pertinent reactions noted above are summarized in Scheme I.

A mixture prepared by the successive addition of 7.4 g (66 mmole) of *t*-BuOK, 4.9 g (66 mmole) of *t*-BuOH, 8.6 g (60 mmole) of di-*t*-butylnitroxide,[8] and 12.5 g (60 mmole) of 1-iodocyclohexene to 60 ml of DMSO, on heating at 60°,[1] gave the characteristic mixture of C_8 hydrocarbons[1] and 0.95 g (10%) of 1-*t*-butoxycyclohexene. However, the reaction gave no trace of **1**, the other C_{12} hydrocarbons, or **2**. Significantly, glpc of the residual material from the reaction (bp > 90°/0.5 mm) gave several large volatile product peaks, including one corresponding to di-*t*-butylnitroxide.

In the absence of di-*t*-butylnitroxide, 1-iodo-4-methylcyclohexene and *t*-BuOK:*t*-BuOH in DMSO gives a *ca* 15% yield of a 3:1 mixture of 1-*t*-butoxy-4-methyl- and 5-methylcyclohexene[1] and a 30% yield of **4**,[10] the dimer of 5-methyl-1,2-cyclohexadiene corresponding to **1**, together with small amounts of incompletely characterized C_7 and other C_{14} hydrocarbons. Examination of the residual material by glpc showed that the reaction also gives at least 3 higher molecular weight

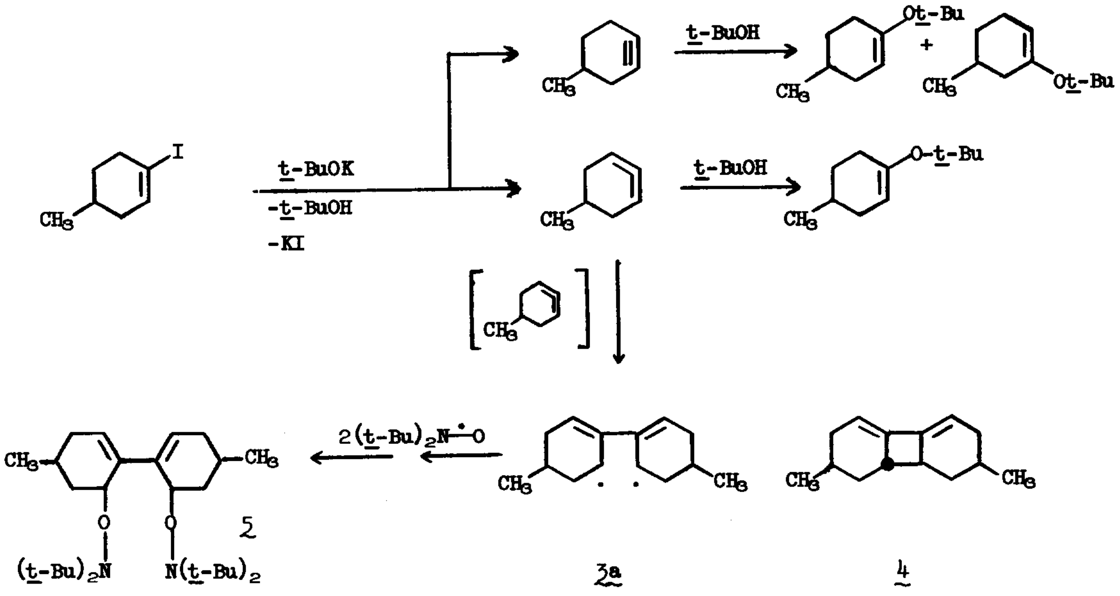
Scheme I



products, in relative amounts of 4:1:1, whose glpc behavior is consistent with what would be expected of methyl-substituted analogs of 2. The rate of formation of these products, relative to that of 4, is similar to that observed for the rates of formation of 2 and 1. Their yield, estimated by glpc, is ca 25%.

A mixture prepared by the successive addition of 3.8 g (33 mmole) of t-BuOK, 2.43 g (33 mmole) of t-BuOH, 4.32 g (30 mmole) of di-t-butylnitroxide, and 6.7 g (30 mmole) of 1-iodo-4-methylcyclohexene to 60 ml of DMSO, on heating at 60° for 5 hr., gave a 2.17-g fraction with bp 30°/40 mm-60°/1 mm, which consisted of C_7 hydrocarbons, t-BuOH, di-t-butylnitroxide, and 0.51 g (10%)of an 82:18 mixture of 1-t-butoxy-4-methyl- and 5-methylcyclohexene, and a 3.6-g residue. Examination of this residue by glpc failed to detect a trace of 4 or the other presumed C_{14} and C_{21} hydrocarbons but gave several large volatile product peaks. Chromatography of the residue on basic alumina with pentane as eluent gave 2.7 g of white, crystalline material. The first 2.0 g eluted had mp 113-118°, which was raised to 120-122° after 2 recrystallizations from MeOH:ether. Analytical and spectral data for this product indicated that it is one or more of the possible diastereomers of 5. [M wt. 505 ± 30 by osmometry in CH_2Cl_2 ($C_{30}H_{58}N_2O_2$ requires 476.8). C, 75.20; H, 11.95; N, 5.82 (Calc. C, 75.57; H, 11.84; N, 5.82). Nmr (CCl_4), δ 5.32 ($W_{1/2}$ = 9 Hz, 1 H), 4.80 ($W_{1/2}$ = 16 Hz, 1 H), and 0.85-2.30 ppm (m, with intense s at δ 1.05 and 1.19 ppm, 27 ± 1 H).[11]]. Our interpretation of these results is shown in Scheme II.

Scheme II



That di-*t*-butylnitroxide undergoes no significant reaction with 5-methyl-1,2-cyclohexadiene is shown by the yield and *composition* of the *t*-butoxycyclohexenes. If such a reaction were of significance, the ratio of 1-*t*-butoxy-4-methylcyclohexene to 1-*t*-butoxy-5-methylcyclohexene would have decreased toward 1:1 from the *ca* 3:1 ratio observed in the absence of the nitroxide. Therefore, the nitroxide must intercept another intermediate in the reaction sequence leading to **4**, and the diradical **3a** is clearly implicated. Thus, the rate of reaction of **3a** and di-*t*-butylnitroxide must be greater than the rate of cyclization of **3a**.

Our results also indicate that di-*t*-butylnitroxide also intercepts intermediates that lead to the [2 + 2] *and* [4 + 2]cycloaddition products of 1,2- and 1,3-cyclohexadiene[1,6] (and their corresponding dimethyl homologs). Di-*t*-butylnitroxide appears to have considerable value as an aid in distinguishing between stepwise and concerted cycloaddition reactions.

References and Notes

[1] A.T. Bottini, F.P. Corson, R. Fitzgerald, and K.A. Frost Jr., *Tetrahedron* **28**, 4883 (1972).

[2] Compound **2** was isolated as a colorless oil by prep glpc at 200° using a 5′ x 3/8″ Carbowax 20M on 30/60 Chromosorb W Column. M. wt. 240.4 (ms). C, 89.87; H, 9.91 ($C_{18}H_{24}$ requires C, 89.94; H, 10.06). Nmr (CCl_4), δ 5.0 - 5.4 (m, 3 H), 1.83 - 3.0 (m, 9 H), and 1.15 - 1.8 ppm (m, 12 H).

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[8] A.K. Hoffman, A.M. Feldman, E. Geldblum, and A.W. Hodgson, *ibid.* **86**, 639 (1964).

[9] A mixture of 2.2 g of *t*-BuOK, 1.5 g of *t*-BuOH, 3.3 g of 1-iodo-4-methylcyclohexene, and 33 ml of DMSO was heated at 60° until the reaction was complete. To a 2-ml aliquot was added 1 ml of DMSO; to a second 2-ml aliquot was added 1 ml of di-*t*-butylnitroxide. These mixtures were heated at 60° for 2 days and examined periodically by glpc under conditions that clearly allowed detection and estimation of the relative amounts of the various products, including the 3 presumed C_{21} hydrocarbons. Comparison of the chromatograms obtained for the 2 samples showed that the relative composition of the various products was unaffected by the added di-*t*-butylnitroxide.

[10] A purified sample of **4**, as an oil, was obtained by prep glpc on Carbowax 20M. M. wt. (ms), 180.3. C, 88.94; H, 10.80 ($C_{14}H_{20}O$ requires C, 89.29; H, 10.71). Nmr (CCl_4), δ 5.20 ($W_{1/2}$ = 8 Hz, 2 H), 0.80 - 2.45 ppm (m, with d, *J* = 6 Hz, at δ 0.96 ppm, 18 H).

[11] The nmr spectra of the crude material and of the material obtained on successive recrystallizations were very similar, but noteworthy changes were observed in the *t*-butyl region. The δ 1.19 ppm peak had a greater height than the δ 1.05 ppm peak in the spectrum of the crude sample, and it also had a significant shoulder at δ 1.16 ppm. Recrystallization resulted in substantial reduction of the intensity of the shoulder and a lowering of the height of the δ 1.19 ppm peak to 90% of the height of the δ 1.05 ppm peak. The mass spectrum of **5** was very complex with an intense peak at m/e of 144 (*t*-Bu_2NO).