The hydrogenolysis product[8] is best removed from the glycol, therefore, by recrystallization of the hydrochloride salt before liberation of the free base.

Fractions 1 and 2 were combined, treated (0.17 g.) with 2 ml. of methyl iodide in 4 ml. of isopropyl alcohol, warmed on the steam bath, then allowed to cool to room temperature. The solid thus obtained was recrystallized from isopropyl alcohol to give 1,1-dimethyl-4-(2-hydroxyethyl)piperidinium iodide, m.p. 169.5–170.5°.

Anal. Calcd. for $C_9H_{20}INO$: C, 37.90, H, 7.07. Found: C, 37.7; H, 6.9.

3-Quinuclidinol (IV).—A 13-mm.-diameter glass reactor tube was packed with 10 g. of Woelm basic alumina (Alupharm Chemicals, New Orleans, La.), then heated to 300° in a muffle furnace, and maintained at that temperature while a stream of nitrogen was passed through at a rate of about 30 ml./min. Then, the piperidyl glycol III, 4.8 g. (0.033 mole), in an open-end glass carrier tube (80 × 10 mm.), was inserted into the reactor tube just to the point where the latter entered the muffle furnace. The apparatus was inclined about 10° downward from the horizontal such that the glycol, when warmed to about 100° with a heating tape, slowly flowed down onto the alumina surface. Product formation was observed a few minutes later, and the reaction appeared to have been completed in less than 1 hr. The product, which had condensed as a viscous liquid in the cold portion of the exit tube, was dissolved in 23 ml. of methanol. Titration of a 1-ml. aliquot of this solution indicated a 43% yield (total base) was obtained. G.l.c. analysis (240°) indicated a composition of about 80% quinuclidinol (4.1 min.), about 15% of an unidentified alcohol (from infrared, possibly 1-azabicyclo [2.2.1]heptyl-7-carbinol) (3.7 min.), and a few per cent of a second unknown product (2.9 min.). (In other runs, minor amounts of several other lower boiling products were also observed.) The remaining 22 ml. of the methanol solution was mixed with about 30 ml. of benzene (to azeotrope the water) and the solvents were removed under reduced pressure. The residue was recycled through another hot column, which now contained 3 g. of Woelm neutral alumina at 190–200°. The first condensate (liquid) was collected in a short collector tube (10-mm. diameter), which had been inserted into the column at its point of exit from the furnace. This forerun was removed, and the product then condensed as a solid and was washed out with methanol. The methanol was evaporated, and heptane was added and evaporated to remove residual methanol. The solid that had precipitated was collected to give 1.34 g. (0.0105 mole, 32%) of 3-quinuclidinol, m.p. 205–210°. The product thus obtained from another run melted at 218–220° (lit.[9] m.p. 221–223°) after trituration with hot heptane, and gave an infrared spectrum (in potassium bromide) which was identical with that of authentic[9] 3-quinuclidinol.

(8) Although not investigated, this side reaction possibly could be prevented by decreasing the proportion of the reduction catalyst and the acidity of the medium, or by changing to an acetic acid solution.

(9) L. H. Sternbach and S. Kaiser, *J. Am. Chem. Soc.*, **74**, 2215 (1952).

Organometallic Chemistry. IX.
The Metalation of Benzocyclobutene with Sodium and Potassium Alkyls[1,2]

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About five years ago, a reaction between butylpotassium and benzocyclobutene (1) was carried out as part of a projected study of the effect of strain on hydrocar-

(2) Paper VIII: R. A. Finnegan and R. S. McNees, *J. Org. Chem.*, **29**, 3241 (1964).

bon acidity.[3] Although this study, which was also to include indane and tetralin, did not materialize, the initial observations with benzocyclobutene, incomplete as they are, seem to be of sufficient interest for publication in this form.

When a freshly prepared suspension of butylpotassium in pentane was stirred for 3.5 hr. with 1 equiv. of 1, followed by treatment with an excess of Dry Ice, only a single acid was obtained in purified form, and this in low yield. An identical acid was later obtained in somewhat higher yield as the sole product (other than caproic acid) after carbonation of a mixture of amylsodium with 1 equiv. of 1 which had been allowed to react for 1 week. This acid had m.p. 188–191° (sublimes) and therefore was not the known α-carboxylic acid which was reported[4] to melt at 76.5°. That this acid was isomeric was evident from the microanalytical results as well as the neutral equivalent, and the conclusion was reached that this material was either the 3-carboxylic acid (2) or the 4-isomer (3). Consistent

2   3
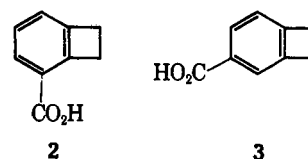
with this conclusion was the carbonyl absorption in the infrared at 1675 cm.$^{-1}$ (KBr) typical for an aromatic acid. Diazomethylation provided the methyl ester, m.p. 50.5–51° (ν_{max}^{KBr} 1727 cm.$^{-1}$), whose ultraviolet spectrum ruled out the possibility that it was a styrene derivative. In view of the fact that metalation of alkyl aromatic substrates usually occurs *meta* or *para* to the alkyl substituent,[5] structure 3 was considered more likely to be correct. This tentative assignment was made in spite of the presence in the infrared spectra of the acid and its methyl ester (2a) of strong bands (779 and 749 cm.$^{-1}$ in the acid, 776 and 729 cm.$^{-1}$ in the ester) attributed to out-of-plane bending vibrations of aromatic CH groups and associated with a 1,2,3-substitution pattern.[6] Reluctance to weigh this evidence heavily was conditioned by the lack of available infrared data on substances of this sort and by the observation that the spectra of methyl 2,3-dimethylbenzoate and 3,4-dimethylbenzoate were not so neatly classified as might have been anticipated. Thus, while the 2,3-isomer displayed a pair of strong bands (763 and 747 cm.$^{-1}$) consistent with the normal correlation,[6] the 3,4-isomer showed only a single strong band in this region (760 cm.$^{-1}$) and even this one occurred at lower frequency than expected.[6]

An unambiguous structural assignment was eventually made after comparison of the n.m.r. spectrum of 2a with those of the two isomeric dimethylbenzoate esters mentioned above. In the accompanying figure are shown tracings of the aromatic proton patterns observed in the spectra of these compounds, and it becomes clear on inspection that the acid resulting from

(3) The potential synthetic utility of the reaction was, of course, not to be overlooked.

(4) M. P. Cava, R. L. Litle, and D. R. Napier, *J. Am. Chem. Soc.*, **80**, 2257 (1958).

(5) R. A. Benkeser, D. J. Foster, D. M. Sauve, and J. F. Nobis, *Chem. Rev.*, **57**, 867 (1957).

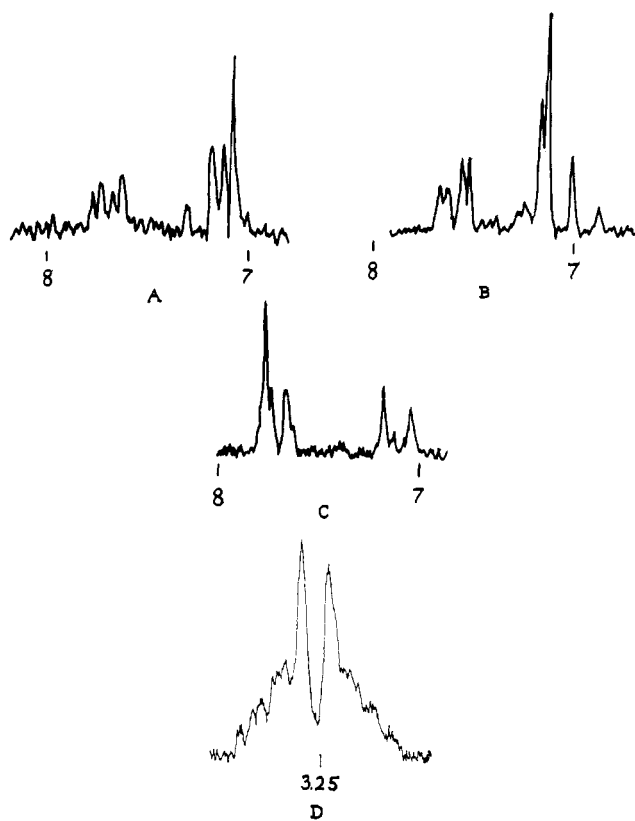(6) K. Nakanishi, "Infrared Absorption Spectroscopy," Holden-Day, Inc., San Francisco, Calif., 1962, p. 27.

Figure 1.—Values are given in p.p.m.: A, methyl benzocyclo-butene-3-carboxylate (2a); B, methyl 2,3-dimethylbenzoate; C, methyl 3,4-dimethylbenzoate; D, benzylic protons in 2a; center lines are 4 c.p.s. apart.

the metalation of 1 must be represented by structure 2, i.e., benzocyclobutene-3-carboxylic acid. In addition to the aromatic region, the features of the C-methyl region are also pertinent to the structural assignment. While the methyls of the 3,4-isomer give rise to a single sharp peak at τ 7.71, the corresponding methyls in the 2,3-isomer are separated by about 9 c.p.s., with one at τ 7.56 and the other at 7.71. Similarly, the methylene groups of the four-membered ring are chemically shifted from one another in 2a, as indicated by the appearance of these protons as an A_2B_2 multiplet centered at τ 6.75. This multiplet is also shown (expanded five times) in Figure 1, the separation between the two center lines being 4 c.p.s. A final verification is inherent in a very recent report of the preparation of benzocyclobutene-4-carboxylic acid (3), whose melting point (139–140°)[7] and spectral properties clearly distinguish it from 2. Thus, all three of the isomeric monocarboxylic acid derivatives of 1 have now been characterized.

Since the first reaction described above was carried out, Benkeser and his students[8] have shown that nuclear metalation of alkyl aromatic hydrocarbons is kinetically favored by both sodium and potassium reagents; however, the final product distribution depends on the relative ease of equilibration of the metal to a benzylic position, as well as on subsequent transformations of the α-metalated species.[8] The increased s character of the α-CH bond orbitals in 1[9] might lead to the expectation

(7) J. B. F. Lloyd and P. A. Ongley, Tetrahedron, 20, 2185 (1964).

(8) R. A. Benkeser, J. Hooz, T. V. Liston, and A. E. Trevillyan, J. Am. Chem. Soc., 85, 3984 (1963), and previous papers.

(9) G. Fraenkel, Y. Ashai, M. J. Mitchell, and M. P. Cava, Tetrahedron, 20, 1179 (1964).

of increased acidity at these positions. It is clear, however, that the conjugate base which would result from metalation at a benzylic position would not enjoy efficient resonance stabilization without the introduction of an increased amount of strain. A similar consideration obtains in the case of cyclopentene where vinyl hydrogen rather than allylic hydrogen abstraction is the observed result of metalation.[10] Unfortunately, the present findings do not rule out the possibility that the α-metalated species is indeed formed, and either exists in a prohibitively small amount in equilibrium with the ring-metalated isomer, or undergoes decomposition by, for example, an elimination reaction to yield an o-metallostyrene derivative whose fate was undetermined.[11]

In conclusion, there remains only to comment on the unique orientation observed in the metalation of 1. The avoidance of metalation ortho to the side chain previously noted in the reactions of simple alkyl aromatic hydrocarbons has generally been ascribed to the steric influence of the side chain, perhaps aggravated by the presumed heterogeneity of the system, as well as to the inductive effect which may serve to lessen the acidity of the ortho hydrogens. In the case of 1, not only is the steric repulsion to ortho attack markedly diminished, but also the hybridization state at C-7 and C-8 (ring-juncture atoms) is such that electron withdrawal from the remaining positions on the benzene ring would be expected. On this basis, then, metalation at C-3 would be predicted to predominate over reaction at C-4. The obtention solely of acid 2 is in qualitative accord with this prediction.

Experimental

Benzocyclobutene-3-carboxylic Acid (2).—To a suspension of potassium sand (3.52 g., 0.09 g.-atom) in pentane (250 ml.) was added during high-speed stirring and over a period of 45 min. 4.6 ml. (0.045 mole) of n-butyl chloride. The first small quantity of the halide was added at −10 to −5°, and then the mixture was allowed to warm up to 10° to ensure the initiation of

(10) R. A. Finnegan and R. S. McNees, J. Org. Chem., 29, 3234 (1964).

(11) It seems pertinent to speculate that had the α-metalated species experienced a sufficient lifetime, a second metalation step might have proved to be energetically beneficial in view of the potential formation of the

4   5
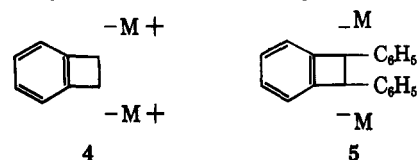
theoretically very interesting disalt 4, which follows the Hückel rule for aromaticity and would be isoelectronic with naphthalene. In order to facilitate the formation of the monosalt, and thus increase the possibility of forming a disalt, it is proposed that 1-phenyl- or 1,2-diphenylbenzocyclobutene might prove to be an effective substrate for the production of species such as 5 in a metalation reaction with sodium or potassium alkyls. W. Adam [Tetrahedron Letters, 1387 (1963)] has attempted, unfortunately without success, to prepare a tetramethylcyclobutadienyl dianion by halogen–metal and hydrogen–metal exchange reactions of an appropriate substrate with lithium reagents. He has suggested that a tetraphenylcyclobutene derivative may prove efficacious, but cautions that the adverse effect of electron repulsion may negate the anticipated resonance stabilization.

the reaction. The mixture was cooled to $-10°$ for the remainder of the addition. Stirring was continued for 50 min. at 0–5° before the addition of 4.27 g. (0.041 mole) of 1.[12] The stirring was stopped 3.5 hr. later (0–5°), and the mixture was forced onto a large excess of powdered Dry Ice. Until this point, the reaction mixture had been maintained in an atmosphere of nitrogen. The carboxylate salts were dissolved in water and extracted with ether. The aqueous layer was acidified with concentrated hydrochloric acid and again extracted with ether. Titration of an aliquot of this ether solution indicated that acidic groups were obtained in 49% yield, based on the amount of butyl chloride used. Evaporation of the ether solution gave 1.80 g. of a residue which was digested in petroleum ether (b.p. 30–60°). The soluble portion was judged to be mainly aliphatic acids by virtue of its odor and infrared spectrum. The insoluble residue provided crystals of 2, m.p. 187–190°, from an aqueous ethanolic solution which had been cooled in an ice box. This material weighed 0.11 g. and represents approximately a 3% yield based on the available organometallic reagent.[13]

A sample of 2 was purified for analysis by sublimation (120°, 0.1 mm.): m.p. 188–191° (sealed capillary); ν_{max}^{KBr} 3300–2300, 1675, 926, 779, and 749 cm.$^{-1}$.

Anal. Calcd. for $C_9H_8O_2$: C, 72.95; H, 5.44; O, 21.60; neut. equiv., 148. Found: C, 72.80; H, 5.37; O, 22.53; neut. equiv., 148.

In another experiment, 5.51 g. (0.053 mole) of 1[12] was allowed to react in a sealed bottle with 0.06 mole of amylsodium suspended in 150 ml. of pentane for 1 week at room temperature. The amylsodium had been prepared from sodium sand and amyl chloride in a manner analogous to that described above for butylpotassium. Carbonation and similar work-up provided, after purification by sublimation, 0.45 g. of 2, m.p. 188–191° (sealed capillary) (6% yield, based on the amount of 1 used).[15]

Methyl Benzocyclobutene-3-carboxylate (2a).—A sample of 2 was treated with ethereal diazomethane to give the ester 2a, which, after two recrystallizations from Skellysolve B, had m.p. 50.5–51°[15]; ν_{max}^{KBr} 1727, 776, and 729 cm.$^{-1}$; $\lambda_{max}^{95\%\ ethanol}$ 241 and 290 mμ (ϵ 8130 and 2560).

Anal. Calcd. for $C_{10}H_{10}O_2$: C, 74.05; H, 6.22; O, 19.73. Found: C, 74.13; H, 5.97; O, 19.90.

The isomeric methyl dimethylbenzoates were similarly prepared by diazomethylation of the commercially available acids.

# A Study of the Mechanism of the Reaction of the Silver Salt of Phenylnitroacetonitrile with Triphenylmethyl Chloride

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The main product of the reaction of the silver salt of phenylnitroacetonitrile (I) with triphenylmethyl chloride has been found to be one of the stereoisomeric α,α'-bis(triphenylmethaneazo)stilbenes (II).[2]

(1) Laboratory of Organic Chemistry, University of Thessaloniki, Thessaloniki, Greece.
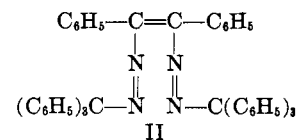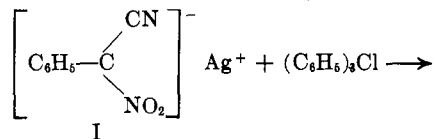
In this reaction benzonitrile oxide (III) was also formed as shown by its interception with phenylacetylene to give 3,5-diphenylisoxazole.[2] The benzonitrile oxide and the triphenylmethyl isocyanate (IV), which had previously been isolated by Wieland and Höchtlen,[3] were proposed as possible intermediates
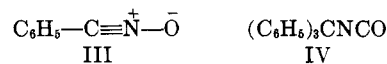
leading to the formation of the product, II. The reaction of compounds III and IV was expected to give carbon dioxide and the nitrilimine V, which might then dimerize to the bisazoethylene derivative II.[2,4]
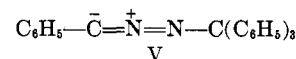
However, the benzonitrile oxide has been found not to react with the triphenylmethyl isocyanate to give compound II. The isocyanate IV was prepared according to Jones and Hurd.[5] Its infrared spectrum in carbon tetrachloride showed peaks at 2260, 1590, and 700 cm.$^{-1}$ and the n.m.r. spectrum of a 12% solution in carbon disulfide had a singlet at τ 2.80. The infrared spectrum of benzonitrile oxide, immediately after its preparation, in carbon tetrachloride was similar to that which has previously been reported,[6] with peaks at 2290, 1710, 1365, 1095, and 1025 cm.$^{-1}$.

The n.m.r. spectrum of a sample after the reaction of the triphenylmethyl isocyanate with the benzonitrile oxide, in carbon disulfide, had peaks at τ 2.80 and 2.60. It was a mixture of isocyanate IV and 3,4-diphenylfuroxan (peak at τ 2.60) produced from dimerization of the benzonitrile oxide.

In order to establish whether the benzonitrile oxide takes any part in the formation of the bisazoethylene II, experiments with labeled benzonitrile oxide (C_6H_5-$C^{14}NO$) were carried out. This radioactive compound was prepared according to the method of Quilico and Speroni,[7] by using labeled benzaldehyde ($C_6H_5C^{14}HO$).

When to a mixture of the silver salt I and triphenylmethyl chloride at $-20°$ a solution of labeled benzonitrile oxide was added, 5.6% of bisazoethylene II, in the form of red crystals, was obtained with m.p. 143° dec. The specific activity of the benzonitrile oxide was 0.693 μc./mmole, measured in the form of 3,4-diphenylfuroxan. Before the addition of the benzonitrile oxide to the reaction mixture its infrared spectrum was obtained; it did not show the presence of

(2) D. Y. Curtin, R. J. Crawford, and D. K. Wedegaertner, *J. Org. Chem.*, **27**, 4300 (1962).

(3) H. Wieland and A. Höchtlen, *Ann.*, **505**, 237 (1933).

(4) D. K. Wedegaertner, Ph.D. Thesis, University of Illinois, 1962.

(5) C. Jones and C. Hurd, *J. Am. Chem. Soc.*, **43**, 2422 (1921).

(6) R. H. Wiley and B. J. Wakefield, *J. Org. Chem.*, **25**, 546 (1960).

(7) A. Quilico and G. Speroni, *Gazz. chim. ital.*, **76**, 148 (1946).