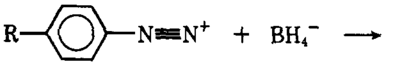
Direct Observation of Diazene Intermediates in Borohydride Reduction of Diazonium Salts. A New Route to Aryldiazenes

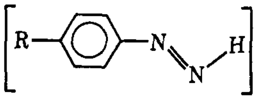
Sir:

The existence of phenyldiazene **2a** as an intermediate[1] in the decomposition of phenyldiazenecarboxylic acid to benzene has been established by Kosower.[2a–e] In several other reactions, notably the base-catalyzed autoxidation of phenylhydrazine,[3] the oxidation of aromatic hydrazines by transition metal salts,[4] diverse reactions of phenyl diazotate,[5] and the reduction of aryldiazonium salts with stannite ion,[6] the formation of transient diazene species has long been suspected.

The more recently discovered reaction of sodium borohydride with benzenediazonium salts[7] presents a relatively simple and convenient system for the detection of a phenyldiazene intermediate. The benzene product might result from transfer of hydride to the carbon atom bound to the diazonium radical, with displacement of molecular nitrogen,[8] but a plausible alternative is nucleophilic attack by borohydride on positive nitrogen, yielding phenyldiazene which subsequently decomposes to the hydrocarbon and nitrogen gas. Studies of deuterium incorporation in bimesityl obtained by the reduction of bimesityl-3,3′-bis(diazonium) bis(tetrafluoroborate) with borodeuteride,[9] and of nitrogenous products from borohydride reduction of 3-nitrobenzenediazonium fluoroborate,[10] have lent support to the second mechanism.



1a, R = H
1b, R = $\cdot NO_2$



2a, R = H
2b, R = $\cdot NO_2$

The availability of spectroscopic constants for phenyldiazene[2c] and a number of its monosubstituted derivatives[11] has encouraged us to attempt the direct observation of a diazene intermediate in the borohydride reduction of a diazonium salt. We wish to report the detection of such intermediates, a success which has synthetic as well as mechanistic significance.

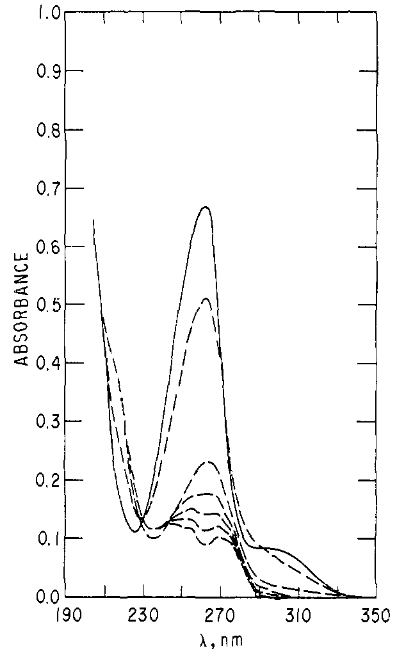


Figure 1. Uv absorption spectrum of **1a** in aerobic phosphate buffer, pH 7: ——, freshly prepared; - - -, after addition of excess $NaBH_4$ (1-min intervals).

We first examined the reduction of benzenediazonium fluoroborate[12] in dilute phosphate buffer under aerobic conditions, using uv spectrometry. The addition of sodium borohydride to a 10^{-4} *M* solution of **1a** in dilute phosphate buffer caused rapid decay of the diazonium peaks at 262 and *ca.* 295 nm. The final spectrum was similar to that obtained by Kosower and Huang[2d] following exposure of an acetonitrile solution of **2a** to air. Strong absorption at 270 nm, corresponding to the formation of **2a**, was not detected, in agreement with the finding that phenyldiazene reacts instantaneously with oxygen (Figure 1).

When this experiment was repeated under anaerobic conditions, we found after addition of borohydride that a new, stable spectrum dominated by a peak at 270 nm had appeared. Over a period of 12 hr this absorbance decreased to the extent of about 35%, and the concomitant decrease of absorbance at 215 nm was commensurate if it is assumed that the new species was **2a** (E_{270} = 7400, E_{215} = 1×10^4; phosphate buffer, pH 7).[2c,d] The solution was then exposed to air, resulting in an immediate shift of the λ_{max} to 274–277 nm and in increased absorption at *ca.* 325 nm (Figure 2).

We have also studied the borohydride reduction of 4-nitrobenzenediazonium fluoroborate (**1b**) since the 4-nitrophenyldiazene (**2b**) is unique among known aryldiazenes in being sufficiently oxygen resistant to permit spectrometric observation in the presence of air.[11] Under aerobic conditions, addition of excess solid sodium borohydride to a 10^{-4} *M* solution of **1b** in acetonitrile produced transformation of the diazonium peak at 259.5 nm into a new peak at 274 nm, with enhanced absorption below 230 nm. Intermediate spectra defined an isosbestic point at 231 nm. The new spectrum closely resembled the published uv

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[1] O. Widman, *Chem. Ber.*, **28**, 1925 (1895).

[2] (a) E. M. Kosower and P.-k. Huang, *J. Amer. Chem. Soc.*, **78**, 4645 (1965); (b) P.-k. Huang and E. M. Kosower, *ibid.*, **90**, 2354 (1968); (c) 2362; (d) 2367; (e) E. M. Kosower, *Accounts Chem. Res.*, in press.

[3] F. D. Chattaway, *J. Chem. Soc.*, 1323 (1907).

[4] A. F. Rekasheva and B. E. Gruz, *Dokl. Akad. Nauk SSSR*, **92**, 337 (1952).

[5] J. E. Jolles, *Gazz. Chim. Ital.*, **62**, 1150 (1932); see also A. Angeli and J. E. Jolles, *Chem. Ber.*, **62**, 2099 (1929).

[6] A. Angeli and J. E. Jolles, *Atti Accad. Naz. Lincei*, **10**, 141 (1929).

[7] S. W. Chaikin and W. G. Brown, *J. Amer. Chem. Soc.*, **71**, 122 (1949); preparative applications of the reaction have been illustrated by J. B. Hendrickson, who introduced the use of isolated fluoroborate salts: *ibid.*, **83**, 1251 (1961).

[8] *Cf.* G. P. Miklukhin and A. F. Rekasheva, *Dokl. Akad. Nauk SSSR*, **80**, 221 (1951).

[9] M. Bloch, H. Musso, and U. I. Zahorszky, *Angew. Chem., Int. Ed. Engl.*, **8**, 370 (1969).

[10] T. Severin, R. Schmitz, J. Loske, and J. Hufnagel, *Chem. Ber.*, **102**, 4152 (1969).

[11] E. M. Kosower, P.-k. C. Huang, and T. Tsuji, *J. Amer. Chem. Soc.*, **91**, 2325 (1969).

[12] The aryldiazonium fluoroborates used were prepared by standard methods. See A. I. Vogel, "A Textbook of Practical Organic Chemistry," 3rd ed, Wiley, New York, N. Y., 1957, p 590 ff.

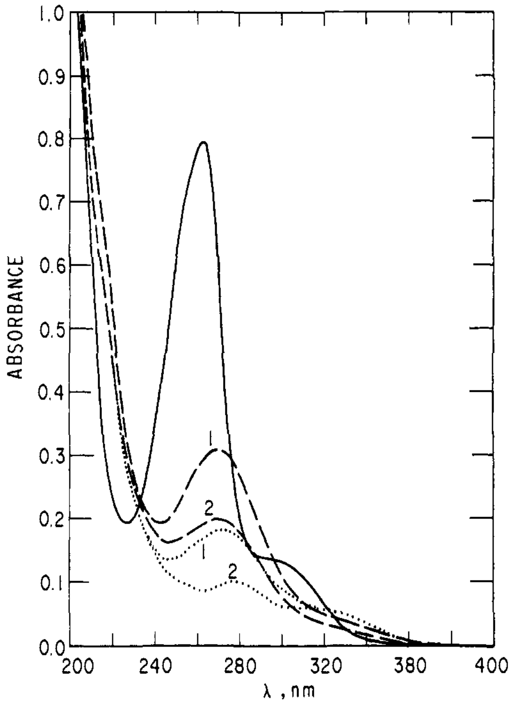

Figure 2. Uv absorption spectrum of **1a** in anaerobic acetonitrile: ——, as prepared; - - -, 1-min (1) and 12-hr (2) after addition of excess $NaBH_4$; . . . , 30 sec (1) and 4 min (2) after exposure to air.

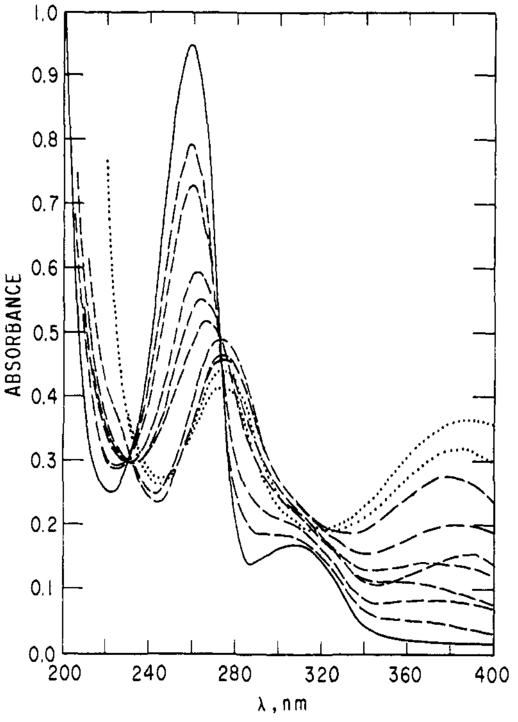

Figure 3. Uv absorption spectrum of **1b** in aerobic acetonitrile: ——, freshly prepared; - - -, 1-min intervals after addition of $NaBH_4$; . . . , 1-min intervals after further addition of excess $NaBH_4$.

spectrum of **2b** ($E_{274} = 12,300$),[11] representing a yield of 61%. Over a period of several minutes the absorption at 274 nm diminished with appearance of a new peak at 368 nm which gradually shifted to 376 nm; an isosbestic point occurred at 322 nm (Figure 3). The peak at 368 nm probably corresponds to the formation of 1,2-bis(4-nitrophenyl)diazane;[11] the gradual bathochromic shift of this peak is due to formation of an as yet unidentified species. When a solution of the species absorbing at 274 nm is made alkaline, the spectrum is drastically altered, indicating the destruction of the initial reduction product; this is in accord with the known sensitivity of aryldiazenes to base.[2d]

We conclude that diazene intermediates are indeed formed in the reduction of benzenediazonium salts by borohydride. Furthermore, the accessibility of the starting materials makes this reduction an attractive route to the synthesis of new aryldiazenes, and may facilitate design of an aryldiazene which is stable to oxygen, or which can be isolated as a pure compound. We are currently exploring these possibilities in our laboratory.

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Dihydro-1,3-oxazines. XIII. Synthesis of Specifically Alkylated Unsymmetrical Ketones. A Method for Assembling Ketones with α-(Quaternary Carbons)

Sir:

There have been a number of recent reports on novel synthesis of ketones possessing diverse structural features which involve organoboranes,[1] organocopper,[2] organoiron,[3] and organolithium[4] reagents. In none of these cases has there been demonstrated that bulky (*e.g.*, tertiary alkyl, isopropyl) substituents can be introduced into the ketone unless the substrate initially contained this preconstructured substituent. This is not surprising since all of the above would require the tertiary alkyl group to be introduced as a halide or its organometallic derivative which are usually unreliable as a source of these moieties.

We now report a method for preparing unsymmetrical ketones **5** and **8** by stepwise introduction of three or four groups, respectively. Furthermore, and perhaps more significantly, the method allows for the preparation of α-(quaternary carbon) ketones of varied structure and specifically alkylated in one of two available sites.

The sequence incorporates an α,α-disubstituted dihydro-1,3-oxazine (**1**) containing two of the substituents (Table I) for the intended ketonic product. These substituents are introduced *via* a variety of facile reactions previously reported from this laboratory.[5]

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(1) H. C. Brown and M. M. Rogic, *J. Amer. Chem. Soc.*, **91**, 4304 (1969); H. C. Brown, H. Nambu, and M. M. Rogic, *ibid.*, **91**, 6852 (1969); H. C. Brown and G. W. Kabalka, *ibid.*, **92**, 714 (1970).

(2) G. H. Posner and C. E. Whitten, *Tetrahedron Lett.*, 4647 (1970).

(3) Y. Sawa, M. Ryang, and S. Tsutsumi, *ibid.*, 5189 (1969).

(4) (a) E. J. Corey and D. Seebach, *Angew. Chem., Int. Ed. Engl.*, **4**, 1075, 1077 (1965); (b) H. M. Walborsky, W. H. Morrison, and G. E. Niznik, *J. Amer. Chem. Soc.*, **92**, 6675 (1970); (c) A. I. Meyers and A. C. Kovelesky, *ibid.*, **91**, 5887 (1969); (d) A. I. Meyers and E. M. Smith, *ibid.*, **92**, 1084 (1970); (e) A. I. Meyers and A. C. Kovelesky, *Tetrahedron Lett.*, 4809 (1969).