Recent data have strengthened previous suggestions as to the possibility of one-electron intermediates in the reactions of pyridine nucleotides.[12-15]

Ion pairs of the type postulated in the present work have been suggested on the basis of the pH dependence of the products from dihydropyrimidinyl radicals formed in radiolysis of dihydropyrimidines.[16] It may be of significance to the consideration of the role of NAD^+ in the enzymatic oxidation of alcohols that photoexcited 9-phenylacridine is reduced to a radical by electron transfer rather than hydrogen atom transfer.[17] The resulting radical pair must then continue to final products by one electron steps. We have pointed out elsewhere the existence of this possibility for NAD^+ in enzymatic reactions,[13,18] and the substituent and isotope effects reported by Klinman are still consistent with this idea.[19]

In the interesting thermal disproportionation reaction of *N,N'*-dicarboethoxy-4,4'-tetrahydrobipyridyl,[20] the transfer of the carboethoxy group and the formation of pyridine might be readily explained by the intervention of an ion pair formed by electron transfer after the formation of the initial radical pair.

(12) K. A. Schellenberg and L. Hellerman, *J. Biol. Chem.*, **231**, 547 (1958).
(13) E. M. Kosower, *Progr. Phys. Org. Chem.*, **3**, 81 (1965).
(14) J. J. Steffens and D. M. Chipman, *J. Amer. Chem. Soc.*, **93**, 6694 (1971).
(15) A. Ohno and N. Kito, *Chem. Lett.*, 369 (1972).
(16) H. R. Hayson, J. M. Phillips, and G. Scholes, *J. Chem. Soc., Chem. Commun.*, 1082 (1972).
(17) A. Castellano, J.-P. Catteau, and A. Lablache-Combier, *ibid.*, 1207 (1972).
(18) E. M. Kosower in "Free Radicals in Molecular Pathology and Biology," Chapter 10, in press.
(19) J. P. Klinman, *J. Biol. Chem.*, **247**, 7977 (1972).
(20) P. Atlani, J. F. Biellmann, R. Briere, and A. Rassat, *Tetrahedron*, **28**, 5805 (1972).
(21) Support from the Army Research Office (Durham) is gratefully acknowledged.

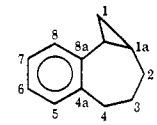
Edward M. Kosower,*[21] Abraham Teuerstein
Department of Chemistry, Tel-Aviv University Ramat-Aviv, Tel-Aviv, Israel
Department of Chemistry, State University of New York Stony Brook, New York 11790

A. J. Swallow
Paterson Laboratories, Holt Radium Institute and Christie Hospital Manchester M20 9BX, England
Received April 21, 1973

Ipso Nitration of an Unsymmetrical Arene.[1] Selective Adduct Formation and Multistep Nitro Group Migrations

Sir:

The importance of electrophilic attack at a substituted position (*ipso* attack[2]) in nitration of certain benzene derivatives has become increasingly clear recently, emphasized by isolation of numerous 1,4 *ipso* adducts.[3] A key experiment by Myhre[4] showed that 1,4 (nitro, acetoxy) adducts of *o*-xylene are converted in strongly acidic media to 3-nitro-*o*-xylene. Postulation of a 1,2-nitro shift sufficed to account for this result; no indications were found of more extensive nitro shifts. We now report that exposure of *ipso* adducts of 1,1a,2,3,4,8b-hexahydrobenzo[*a*]cyclopropa[*c*]cycloheptene (**1**) to strongly acidic media affords

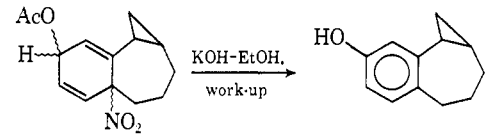


1

evidence that a nitro group can have significantly more mobility in intramolecular rearrangement than previously seen.

Compound **1** appears almost uniquely well suited for the study reported here. The 5-, 6-, 7-, and 8-nitro derivatives of **1** are readily separable and/or distinguishable by pmr analysis,[5] as are the 6- and 7-acetoxy[6] and 6- and 7-hydroxy[6] derivatives. Nitration of **1** (6 mmol in 2 ml of acetic anhydride) with acetyl nitrate (preformed from 9 mmol of 100% nitric acid and 2 ml of acetic anhydride) gave up to 60% of *ipso* adducts, in addition to "normal" nitration products, as indicated by comparison of pmr integrated intensities of vinyl (δ 6.01–5.95) *vs.* aryl (δ 8.17–7.18) proton resonances.[3] The nitro derivative mixture consisted of 40% each of 6- and 7-nitro-**1**, 11% of 5-nitro-**1**, and 9% of 8-nitro-**1**.[7]

Welcome simplification of the adduct identification problem was provided by treatment of the crude nitration mixture with ethanolic alkali; work-up yielded a nearly quantitative amount of a mixture of all four nitro derivatives and 7-hydroxy-**1**. The absence of detectable amounts of 6-hydroxy-**1** showed that essentially exclusive formation of adducts having gross structure **2** had occurred.



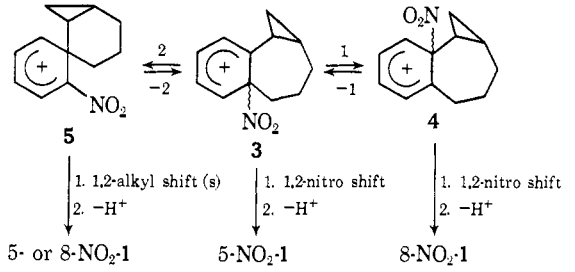
2

Rapid chromatography of the crude reaction mixture over deactivated alumina afforded a stable stereoisomer of **2**: colorless crystals; mp 86–87.5°; pmr (CCl_4) δ 6.01 (broad s, 2 H), 5.95 (m, 1 H), 5.53 (m, 1 H), and 2.08 (s, 3 H).[9] Passage of this pure adduct through a silica gel column effected conversion to pure 7-acetoxy-**1**.[6] However, when the adduct was solvolyzed in 78% sulfuric acid (2 min, 25°), in addition to the 5-nitro-**1** expected from a 1,2-nitro shift (41%), there was obtained 54% of 8-nitro-**1** and *ca.* 5% of a mixture of 6- and 7-nitro-**1**.[10]

(1) Part V in a series on cyclopropylarene chemistry. Part IV: G. R. Elling, R. C. Hahn, and G. Schwab, *J. Amer. Chem. Soc.*, **95**, 5659 (1973).
(2) C. L. Perrin and G. A. Skinner, *J. Amer. Chem. Soc.*, **93**, 3389 (1971).
(3) As leading references, see (a) A. Fischer and J. N. Ramsay, *J. Chem. Soc., Perkin Trans. 2*, 237 (1973); (b) A. Fischer and A. L. Wilkinson, *Can. J. Chem.*, **50**, 3988 (1972); A. Fischer and D. R. A. Leonard, *ibid.*, **50**, 3367 (1972); A. Fischer, C. C. Greig, A. L. Wilkinson, and D. R. A. Leonard, *ibid.*, **50**, 2211 (1972).
(4) P. C. Myhre, *J. Amer. Chem. Soc.*, **94**, 7921 (1972).
(5) R. C. Hahn and P. H. Howard, *ibid.*, **94**, 3143 (1972), and references therein.
(6) Independently prepared from the corresponding nitro compounds by standard procedures.
(7) The failure of the cyclopropyl group to exert dominant directive effects in nitration of **1** is of intrinsic interest,[8] and will be discussed in our full paper.
(8) *Cf.* L. M. Stock and P. E. Young, *J. Amer. Chem. Soc.*, **94**, 4247 (1972).
(9) Satisfactory elemental analyses were obtained.
(10) The overall yield of nitro isomers from adduct solvolysis was *ca.* 50%. A variety of solvolysis methods gave no improvement, and

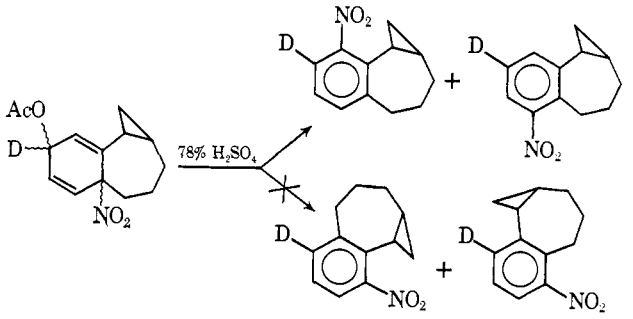
A number of explanations of this result were possible *a priori;* of these, reversion of nitrophenonium ion **3** to **1** or "encounter pair"[4] could be excluded as a major contributor to the rearrangement mechanism, since nitration of **1** gives such a drastically different isomer distribution (*vide supra*).[11] Other possible reaction pathways for **3** are outlined in Scheme I. Omitted

Scheme I



from this scheme are 1,3 shifts, on the basis of orbital symmetry considerations, and 1,2-alkyl shifts originating from **4**, for momentary simplicity. Although alkyl migration (step 2) is rendered unlikely by the destabilizing effect of the nitro group in **5** (relative to **3**), rigorous exclusion of this mechanism seemed desirable in view of the unprecedented nature of the transformations of **3**. It should be stressed also that the conversion of **3** to 8-NO_2-**1** may find parallels in such well-studied *o*-dialkylbenzenes as *o*-xylene,[4] indan,[3] and tetralin,[3] but that these parallels would be undetectable in the latter systems because of their symmetry properties.

The lack of symmetry in **1**, however, in addition to allowing observation of extensive nitro shifts, enabled us to obtain experimental results essentially ruling out step 2 *et sequelae*. The monodeutero compound **1**-7-d_1 was prepared[12] and converted to the corresponding crystalline *ipso* adduct. Exposure of the latter to 78% sulfuric acid afforded 5- and 8-NO_2-**1**-d_1 in which no change in the apparent position of the deuterium could be detected. The nitro group in **3** therefore must shift



at least once, and since step 2 (Scheme I) and any subsequent alkyl shifts are excluded, a second nitro shift from **4** seems much more likely than any alkyl shifts involving that species.[13] The absence of detectable amounts of *ipso* adducts derived from ion **4** indicates that this is a considerably more energetic species than **3**, although the transition-state barrier from **4** → 8-NO_2-**1** must be slightly *lower* than the barrier from **3** → 5-NO_2-**1**.

Nitration of **1** in 82% sulfuric acid gave 18% of 5-nitro-**1**, 24% of 8-nitro-**1**, and 58% of 6- and 7-nitro-**1**, with no detectable acetoxylation products; this is the same isomer distribution, within experimental error, as that obtained from strong acid solvolysis of an acetyl nitrate–acetic anhydride nitration mixture containing 40% *ipso* adducts. The available evidence strongly suggests that the bulk of 5- and 8-nitro-**1** isolated from sulfuric acid nitration is derived from initial *ipso* attack followed by nitro shifts and deprotonation; the *caveat* of Myhre[4] and Perrin[2] thus is underscored: *true partial rate factors in aromatic substitution of certain substrates cannot be obtained without determination of the extent and consequences of ipso attack.*[14]

Structural effects on the formation and rearrangement of *ipso* adducts are under further study.

Acknowledgment. Support of this research by the donors of the Petroleum Research Fund, administered by the American Chemical Society, principally in the form of a PRF Postdoctoral Fellowship to M. B. G., is gratefully acknowledged.

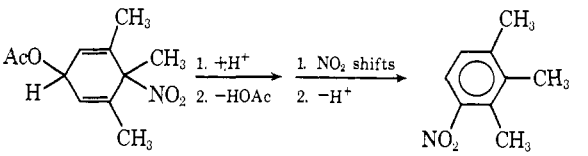
we conclude that some of the nitrophenonium ion **3** in acidic medium is transformed readily to products other than simple nitro compounds. Direct nitration of **1** in acidic medium gave *ca.* 75% overall yields of nitro compounds; the missing 25% again is consistent with diversion of half of the initially formed **3** to other products. The nitro derivatives of **1** were shown to be stable to all nitration and solvolysis conditions used.

(11) Reversible expulsion of NO_2^+ from **3** cannot be excluded as a minor possibility. For this minor component, reattack would afford "normal" proportions of 6- and 7-nitro-**1**, sufficient to account for the observed 5% of these isomers. This possibility is under study.

(12) Deuterium incorporation was greater than 80% by pmr analysis; synthesis details will be given in our full paper.

(13) Two 1,2-cyclopropyl shifts from **4** would produce 5-NO_2-**1**-d_1 with no apparent deuterium change, so that this possibility remains, though it is considered remote.

(14) Myhre has found (private communication) that acid solvolysis of 4-nitro-3,4,5-trimethylcyclohexa-2,5-dienyl acetate affords only 4-nitrohemimellitene



We thank Professor Myhre for this further example of a multistep nitro group migration.

Roger C. Hahn,* Marinus B. Groen
Department of Chemistry, Syracuse University
Syracuse, New York 13210
Received May 24, 1973

Stereospecific Rearrangement of Strained Cyclobutylcarbinyl Cations[1]

Sir:

By comparison with the extensively studied cyclopropylcarbinyl cation system,[2] a paucity of information exists concerning the cyclobutylcarbinyl cation. We now wish to report on a stereospecific rearrangement of a cyclobutylcarbinyl cation which involves the ring expansion of the four-membered ring of the tricyclo-[4.2.1.$0^{1,6}$]nonane skeleton.[3]

(1) Paper XLII in the series The Chemistry of Bent Bonds. For the preceding paper in this series, see: P. G. Gassman, R. N. Steppel, and E. A. Armour, *Tetrahedron Lett.*, in press.

(2) For recent reviews of this subject see, H. G. Richey, Jr., in "Carbonium Ions," Vol. III, G. A. Olah and P. v. R. Schleyer, Ed., Wiley-Interscience, New York, N. Y., 1972, pp 1201–1294; see also K. B. Wiberg, B. A. Hess, Jr., and A. J. Ashe, III, *ibid.*, pp 1295–1345.

(3) This ring system can also be named as a [4.2.1]propellane. For an explanation of propellane nomenclature see J. Altman, E. Babad, J. Itzchaki, and D. Ginsburg, *Tetrahedron, Suppl.*, No. 8, 279 (1966). See also D. Ginsburg, *Accounts Chem. Res.*, 2, 121 (1969); 5, 249 (1972).