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# INVOLVEMENT OF THE INTRAMOLECULAR IONIC REACTION IN THE STERIC COMPRESSION-ASSISTED REACTION (STECAR) CONCEPT. REARRANGEMENT OF BORNYL α-AZO BENZOATE INTO LACTAM

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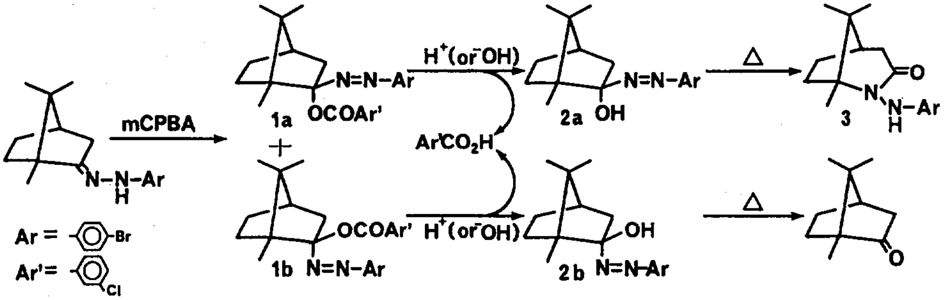
Abstract: The importance of the polarization and ionic reaction phenomena in the steric compression-assisted reaction (STECAR) concept is described.

Much attention has been paid to the theory of the proximity effect for the facile intramolecular reaction in recent years.[1,2] We have recently reported the steric compression-assisted reaction (STECAR) concept that states the importance of the polarization of the reacting moiety caused by the steric effect of the bulky substituent located nearby and the subsequent intramolecular ionic reaction phenomena.[3,4] However, it seems that the polarization and ionic phenomena in the STECAR concept are not well understood. And, it is necessary to obtain evidence clarifying these points and to describe them more precisely. Now, we report a new rearrangement of bornyl α-azo benzoate into lactam and related data, which indicate the important involvement of the intramolecular ionic reaction in the STECAR concept.

The α-azo benzoate 1 (mp 113°C) was obtained by the reaction of camphor hydrazone with m-chloroperbenzoic acid in benzene at room temperature in a high yield; 1 is a 1:1 mixture of the endo- (1a) and exo- (1b) benzoates.[5] The benzoate 1 is thermally stable and unreactive in benzene. However, when 1 was refluxed in ethanol in the presence of dilute hydrochloric acid (1N), the lactam 3[6] and camphor were formed each in ca. 40% yield. Similarly, the thermal base-catalyzed reaction of 1 gave 3 in 40% yield accompanied by camphor (Scheme 1).

These products arise via the corresponding azo alcohol intermediates generated by hydrolysis of 1a,b. Indeed, the alcohol (2) in the acid catalyzed reaction of 1 was identified by means of HPLC. And, we also observed that the azo alcohol 2 (endo and exo mixture) prepared independently by the reduction of bornyl azo hydroperoxide[6] gave lactam (3) and camphor when refluxed in acidic ethanol. These facts together with knowledge of our previous work on the bornyl α-azo alcohols indicate that the lactam 3 and camphor came from the endo- and exo-alcohols (2a and 2b),[6] which are generated from 1a and 1b by hydrolysis in the reaction of 1, respectively. Therefore, the acid and base catalyze the hydrolysis of 1 to give 2, and the thermal reaction converts 2 to the products (Scheme 1).

Scheme 1

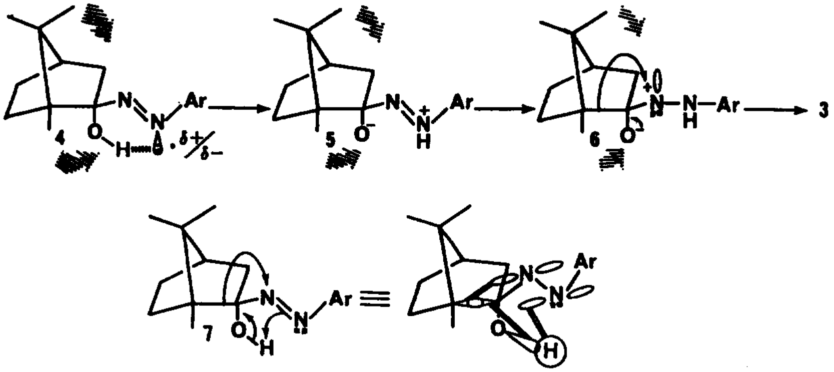


The structure-reactivity relationship observed above is in accord with that reported previously for bornyl, norbornyl, and fenchyl α-azo alcohols, on which the STECAR concept is based.[3,4,6,7] Therefore, in the present study we took the above reaction as the model together with the reaction of α-azo alcohols (2), and undertook several tests necessary to see the intramolecular ionic reaction phenomenon.

A higher concentration of the acid such as 5N-HCl somewhat lowered the yield of the lactam 3 in the reaction of 1 but did not stop the lactam formation. Regardless of the acid- or base-catalyzed reaction, 1 gave 3 in nearly the same yield. Similarly, the lactam 3 was formed from the azo alcohol 2 prepared independently, by the thermal reaction in acidic ethanol as well as in neutral benzene. These observations indicate that the external acid and base do not crucially influence the formation of the lactam 3 from the azo alcohol 2a. This suggests that the reactive species responsible for the rearrangement such as 6 is generated by the intramolecular reaction but not by the acid- and/or base-catalyzed reaction (Scheme 2).

Molecular orbital and model consideration has revealed that the orbital overlapping of the N=N π-, $C_1$-$C_2$ σ-, and O-H σ-bonds for the lactam rearrangement in the concerted manner ($_{\pi}2_s + _{\sigma}2_s + _{\sigma}2_s$) indicated by 7 or 8 is extremely unfavorable. For example, the $C_1$-$C_2$ σ- and N=N π-orbitals are oriented in the orthogonal position in 8. On the other hand, the intramolecular hydrogen bonding with the lone pair $N_\beta$ electrons, the orbital of which is projected perpendicular to the N=N π-orbital indicated by 4, is

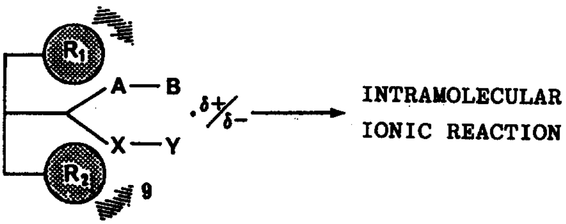
Scheme 2



easily attainable. This suggests that the rearrangement is not a concerted reaction but a stepwise one. Of course, the rearrangement is not a radical reaction. The only way which satisfies the above requirements is the ionic reaction pathway involving the 1,2-shift of the $C_1$-$C_2$ σ-bond onto the positively charged nitrogen atom or nitrenium ion at the $N_\alpha$ in 6, which is generated transiently from 5 that is formed from 4 by the intramolecular proton shift caused by the STECAR. It is important to note that the 1,2-shift of the alkyl group onto the positively charged nitrogen atom or nitrenium ion, as in 6, is well documented in the rearrangement of norbornyl-2-exo-chloronitrenium ion into the 2-azabicyclo[3.2.1]octan system, and that of azabornyl derivatives, etc.[8-11]

By joining the present and previous results,[4,6] we can now explain the rearrangement in terms of the STECAR concept as follows.[3] Steric repulsion by the 8- and 10-methyl groups fixes 2a to the stable hydrogen bonding conformer 4, and the steric compression effect by the methyl group thus substantiated[12] induces the polarization of the arylazo and hydroxyl moieties. This brings about the facile intramolecular proton shift[13] giving rise to 5 and subsequently 6 which rearranges into the product or 3. These transformations occur ionically and consecutively in one molecule.

Scheme 3



Therefore, it can be said that the STECAR concept comprises the polarization of the reacting moieties (A, B, X, and Y) (9) caused by the steric effect of the bulky substituents located nearby ($R_1$ and $R_2$), and the subsequent intramolecular ionic reaction (Scheme 3). And, this concept differs from the hitherto known concept or theories of the steric effect[14,15] and the proximity effect for the facile intramolecular reaction.[1,2]

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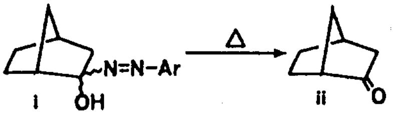
7) The norbornyl α-azo alcohol (i) (endo and exo mixture), for example, gave no lactam but only the decomposition product (ii) by the thermal reaction (see Ref. 6).



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13) Details of the intramolecular proton shift including the kinetic deuterium isotope effect will be reported elsewhere.

14) This includes steric acceleration of the reaction rate by B-strain and I-strain, and/or the buttressing effect, etc. See N. S. Isaacs, "Physical organic chemistry", Longman Scientific & Technical (Burnt Mill), 1987, pp. 282 - 329.

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