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# CONCERNING THE MECHANISMS OF THE WOLFF REARRANGEMENT; A DISSIMILARITY BETWEEN THE THERMAL WOLFF AND CURTIUS REARRANGEMENTS

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It is commonly assumed that the ketocarbene-ketene mechanism, usually cited for the Wolff rearrangement of diazoketones in the Arndt-Eistert synthesis[1,2] (see scheme a, formulas ABCD), has experimental support. Largely ignored, however, is the alternative mechanism proposed by Eistert in 1935,[3] which involves addition of an alcohol (or water or an amine) prior to loss of nitrogen. In one of its forms which we have used (scheme b),[4] the alcohol is postulated to add to the diazoketone A with protonation of the diazocarbon to form a zwitterion E in a rapidly equilibrating step, followed by concerted loss of nitrogen and rearrangement directly to the homologous ester D.

The ketocarbene-ketene mechanism, which has been applied widely to the catalytic,[a] thermal and photochemical processes, was originally proposed by analogy to the Curtius and related

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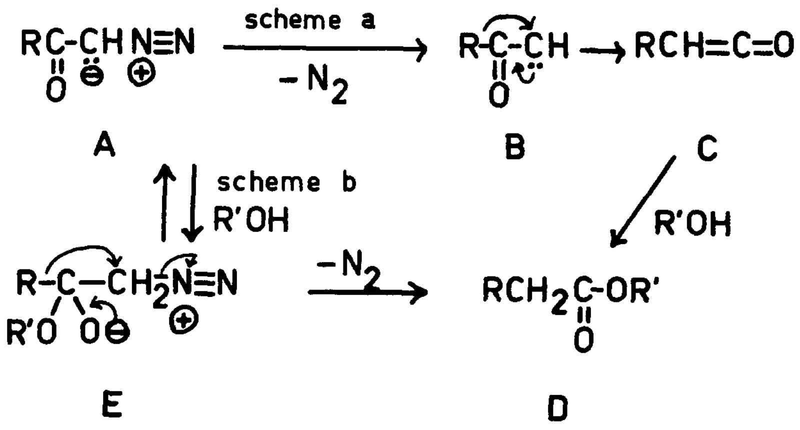
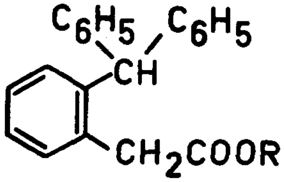
[a] An exception is the silver benzoate-methanol-triethylamine rearrangement process, which has been formulated as a radical reaction.[5]

rearrangements, and the well-known thermal rearrangement of phenylbenzoyldiazomethane to diphenylketene.[1a] One reason for Eistert proposing the alternative mechanism was that reduced resonance stabilization due to protonation of the diazocarbon would result in faster reaction of the zwitterion E than of the diazoketone A. As far as we are aware, there has been no evidence which distinguishes between these two mechanisms under the actual conditions of the Wolff rearrangement, except possibly for the relatively recent photochemical process.

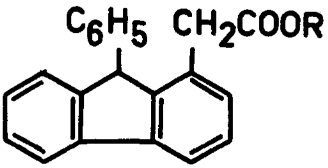
Some years ago[4a] we started experiments to see how increasing steric hindrance would affect the formation or rearrangement of diazoketones, and for the latter looking for examples of abnormal reactions that might throw light on the process. In the case of triphenylacetyldiazomethane (A, R=$(C_6H_5)_3C-$ ) we found[6] that the silver-catalyzed or the more reliable thermal rearrangement,[7] in a high boiling alcohol and tertiary amine at 150-180°, did not give the normal product D. Instead the thermal process gave the ester of an abnormal isomer, triphenylmethane-*o*-acetic acid (F), and a second abnormal ester having a dimeric structure.[6] That these abnormal products are indicative of steric inhibition of the normal thermal process, was supported by the fact that diphenylacetyldiazomethane gave the normal product under these conditions.[4a] Furthermore, in the case of 9-phenylfluorene-9-carbonyldiazomethane, which is intermediate in steric hindrance, the thermal rearrangement gave both normal (D, R=9-phenyl-9-fluorenyl) and abnormal (G) products.[6]

In contrast to these abnormal Wolff rearrangement products, the Curtius rearrangement of triphenylacetylazide occurred





F



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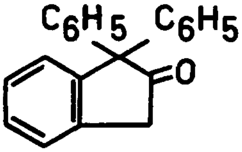

H

$$(C_6H_5)_3C\text{-}\underset{\substack{\Vert \\ O}}{C}\text{-}NHNH\text{-}\underset{\substack{\Vert \\ O}}{C}\text{-}C(C_6H_5)_3$$

I

readily on warming to give the normal isocyanate.[4b] This difference makes any mechanistic analogy between the thermal Wolff and Curtius rearrangements weak.

On the other hand, the photochemical Wolff rearrangement process, by irradiation in tetrahydrofuran-water solution, proceeded normally for both triphenylacetyldiazomethane and 9-phenyl-9-carbonyldiazomethane to the acids of type D.

Regarding the mechanisms of these Wolff rearrangement processes, we tend to concur in the view that the currently known facts about the photochemical method are in satisfactory agreement with the ketocarbene-ketene scheme, with the insertion of an excited state (A*) before initial nitrogen loss, and leaving unanswered the question of the energetic state of the ketocarbene B (electronically excited singlet or triplet, or vibrationally energized ground state).

The ketocarbene-ketene mechanism allows no simple rationalization of the abnormal course of these thermal Wolff rearrangements versus the normal photolyses and Curtius rearrangement.[b] The alcohol addition-protonation mechanism readily accounts for the differences observed, which fit in well with the degree of steric hindrance about the carbonyl carbon after addition of alcohol; Fisher-Hirschfelder models for triphenylacetyldiazomethane and 9-phenylfluorene-9-carbonyldiazomethane show that the geometry is more favorable for electrophilic attack by the

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b) We recognize, of course, that the argument can be made that a ketocarbene from the thermal and photolytic processes need not be the same species or react similarly. Considering all of the facts in the present case, however, including the thermal results in the absence of alcohol, we consider this argument scientifically weak, especially in the absence of any evidence for a ketocarbene in the thermal process.

diazonium carbon at the aromatic ring than for normal rearrangement.

The abnormal results with triphenylacetyldiazomethane cannot be explained in terms of cyclization to the 2-indanone (H), followed by ring opening. The indanone H was not isolated when the diazoketone was heated in γ-collidine in the absence of an alcohol. The products isolated were triphenylmethane and, surprisingly, the diacylhydrazide I.[4a,8] Furthermore, the indanone H was recovered after subjecting it to conditions similar to those of rearrangement and hydrolysis.

The fact that the products obtained in the absence of an alcohol were different from those of the thermal Wolff rearrangement is consistent with the contention that alcohol is involved in the rate-determining step. Morrison and Yates[9] have presented convincing evidence that an alcohol can protonate a diazoketone at the diazocarbon; they found a half-life of 14 hours for exchange of hydrogen on the diazocarbon by deuterium in deuteriomethanol at room temperature. Although the presence of tertiary amine in the thermal rearrangement might catalyze this, simple calculation indicates a half-life of less than 12 seconds at 150°.

We suggest that all of the results presently available for the thermal Wolff rearrangement are in better agreement with the addition-protonation mechanism than for the ketocarbene-ketene mechanism. Of most importance, however, we want to underscore the lack of significant mechanistic evidence for the thermal Wolff rearrangement. Since it, like the Curtius rearrangement, can be carried out in homogeneous solution and followed by measurement of nitrogen, this lack of evidence is surprising, and merits the attention of experts. While the efforts of Yates and coworkers[10] on the Wolff rearrangement indicate there are obstacles in the way of meaningful kinetic results, we suggest that a suitable choice of solvent and compound should lead to significant results, and particularly from experiments designed to discriminate between the two types of mechanism. The wide range of alcohols (and even phenol) which can be used successfully in the thermal Wolff process[7] makes it suitable for study of the effect of this reagent as well. Finally, it should be emphasized that arguments based upon products from diazoketones heated in the absence of an alcohol cannot provide meaningful evidence against the alcohol addition-protonation mechanism, although in certain cases, as with the present examples, these results may be valid arguments against the ketocarbene-ketene mechanism, which should not require the alcohol in the early stages of the reaction.

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