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CONFORMATIONAL CONTROL OF DECOMPOSITION PATHWAYS OF α-DIAZOKETONES.[1]

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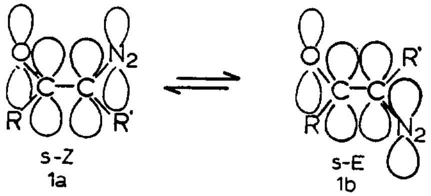
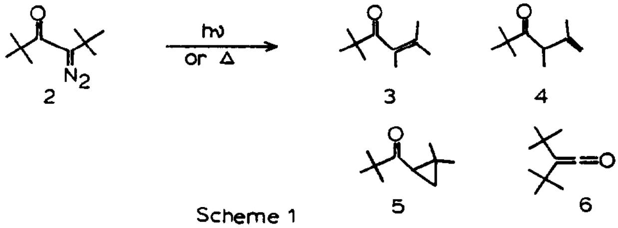
α-Diazoketones are known to rearrange to ketenes with the loss of nitrogen under thermal, photochemical or catalytic conditions.[2] Although dynamic nuclear magnetic resonance techniques (dnmr) have been used to show that α-diazoketones can exist in solution as an equilibrium mixture of s-Z (1a) and S-E (1b) conformers,[3-5] the role of conformation in the decomposition of α-diazoketones has been virtually ignored. We wish to report evidence which shows that under aprotic thermal or photolytic conditions ketene formation (the Wolff rearrangement) proceeds preferentially from an s-Z conformation in which the migrating group lies trans to the departing nitrogen moiety. Heretofore, only fragmented data has been cited to support this selectivity.[6]



s-Z
1a

s-E
1b

The di-t-butyl substituted α-diazoketone, 2,2,5,5-tetramethyl-4-diazo-3-hexanone (2), serves as the best example of an s-E dominated α-diazoketone (vide infra) while 3,3,6,6-tetramethyl-2-diazocyclohexanone (7), a cyclic α-diazoketone, serves as an s-Z locked analog of 2. Newman and Arkell[7] originally prepared and decomposed 2 under thermal, photolytic and catalytic conditions (Scheme I). The major product in each case was 2,2,4,5-tetramethy-4-hexen-3-one (3). Minor amounts of isomeric ketones, 4 and 5, were also obtained. Significantly, di-t-butylketene (6) was not detected to any appreciable extent (<4%) although it was later prepared by a different synthetic route.[8]



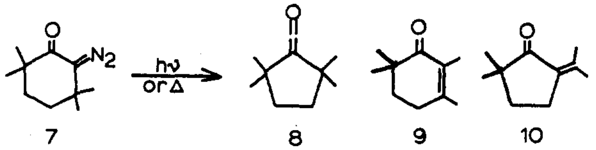
Scheme 1

The method of Newman and Arkell[7] was used to prepare 2. Purification was effected by chromatography through a silica gel column using benzene as an elutant (IR (neat): 2050 cm^{-1}, 1630 cm^{-1}; UV (95% EtOH): λmax = 420 nm (ε~ 26), 290 nm (ε~ 2900)). Heretofore, the discussion has presupposed 2 exists predominately in an s-E conformation due to severe steric crowding of eclipsed t-butyl groups. The room temperature nmr spectrum (CCl$_4$) of 2 consists of two sharp singlets of equal intensity at δ 1.17 and 1.23. The addition of Eu(fod)$_3$ in a 0.7 molar ratio moves these singlets downfield and increases the difference in shift between them to 1 p.p.m.; however, even at -17° no splitting or broadening of the signals is observed. This is in sharp contrast to the case of 3-diazo-2-butanone which has a coalescence temperature of approximately +13°.[4] A difference of 9.3 kcal/mole in the heats of hydrogenation of Z- and E-di-t-butylethylenes[9] makes it reasonable to assume that the s-Z conformer of 2 is approximately 9 kcal/mole higher in energy than the s-E conformer resulting in a s-Z/s-E population ratio of ~ 1 x 10^{-7} ,

Photolysis[10] of 2 in either CCl$_4$, dioxane or Cl$_2$CCCl$_2$[11] afforded 3[12], an α, β-unsaturated ketone in 78% yield and 5[13], an isomeric ketone in 17% yield. Thermolysis of 2 in Cl$_2$CCCl$_2$ at 120° afforded 3 and 5 in yields of 81% and 16%, respectively. The presence of di-t-butylketene (6) was not detected. The findings are in good agrement with those of Newman and Arkell.[7]

The previously unreported 3,3,6,6-tetramethyl-2-diazocyclohexanone (7) was prepared from 3,3,6,6-tetramethylcyclohexan-1,2-dione[14] via its tosylhydrazone (m.p. 85-86° dec.) using the method of Muchowski.[16] Purification of 7 was effected by chromatography on a 20 cm x 20 cm x 1 mm silica gel plate using chloroform as the elutant [NMR (CDCl$_3$): δ 1.15 (s,6H), 1.25 (s,6H), 1.67 (s,4H); IR (neat): 2070 cm^{-1} 1630cm^{-1}; UV (95% EtOH): λmax = 395 nm (ε~ 7), 288 nm (ε~2700)].

In sharp contrast to the case of the s-E dominated α-diazoketone, 2, photolysis of 7 (Scheme 2), an s-Z locked α-diazoketone, in either anhydrous CCl$_4$ or dioxane afforded the ring contracted ketene 8 in 96% yield [NMR (CCl$_4$): δ 1.25 (s,12H), 1.68 (s,4H); IR (neat): 2090 cm^{-1}]. The minor product from the photolysis of 7 was an α ,β -unsaturated ketone, 9 or 10.[17-19] [NMR (CCl$_4$): δ 1.08 (s,6H), 1.50 -2.83 (m,10H); IR (neat): 1700 cm^{-1}, 1630 cm^{-1}]. Thermolysis of 7 in either CCl$_4$(70°,6 hrs.) or Cl$_2$CCCl$_2$ (110°, 30 min.) afforded 8 in 85% yield and 9 or 10 in 15% yield.

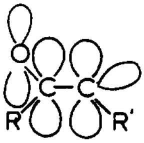


Scheme 2

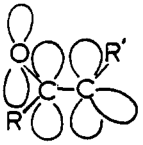
Ring contractions in cyclic α-diazoketones are not uncommon, but the striking difference in products obtained from this conformational pair (2 and 7) under controlled decomposition conditions clearly demonstrates a conformational requirement for ketene formation in both photochemical and thermal Wolff rearrangements. Controversy concerning the sequence of events in the Wolff rearrangement has centered upon the question of whether alkyl migration occurs with concerted loss of nitrogen or through intermediates. Labeling experiments by Strausz and co-workers[23] have shown the existence of oxirenes and hence ketocarbenes as intermediates in the photolytic decomposition of selected acyclic α-diazoketones. However, Timm, Zeller and Meier[24] found no oxirene participation in the photolysis of labelled 2-diazocyclohexanone. Furthermore, CIDNP studies by Roth and Manion[25] suggest singlet acetylmethylene is not an intermediate in the unsensitized photolysis of diazoacetone. Thus, the possibility of more than one mechanism for ketene formation must be considered.

The conformational control shown by 2 and 7 is in accord with a concerted process for the Wolff rearrangement. In a concerted transformation, only an s-Z conformer would allow facile backside attack by the migrating alkyl group on the diazo-carbon. The failure of the E-dominated α-diazoketone, 2, to undergo ketene formation can be attributed to its inability to assume an s-Z conformation before decomposing to other products by less eneretic pathways. The s-Z locked model, 7, which is open to backside displacement of nitrogen by the migrating alkyl group, readily undergoes ketene formation.

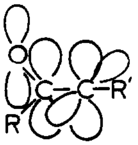
The conformational control we have observed is consistent with intermediate ketocarbene formation only if the structures 11a and 11b, generated directly from the s-Z and S-E conformers, respectively, retain the conformational identity of their precursors. Neither the linear sp hybridized structure, 11c, nor the rotated sp^2 structure, 11d[26], possess any such conformational identity.



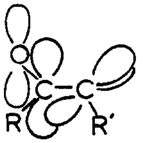
11a



11b



11c



11d

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10. Photolysis was effected with an argon ion laser (Coherent Radiation Co.) set for visible irradiation with several lines between 454 and 514 nm with an output of 3-6 watts.
11. Solvents employed in the decompositions of 2 and 7 were freshly distilled and were passed through a column of basic alumina to remove any protolytic impurities. This was done to preclude the formation of products, especially 3, 9, and 10, through a diazonium ion. In the presence of aqueous HCl, 7 decomposed in 20 min at 50° C to form only 9 or 10.
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