Tetrahedron Letters No. 2, pp 93 - 96, 1978. Pergamon Press. Printed in Great Britain.

THE [6+4] PHOTOCYCLOADDITION OF 3-PHENYL-2,2-DIMETHYL-2H-AZIRINE TO FULVENES

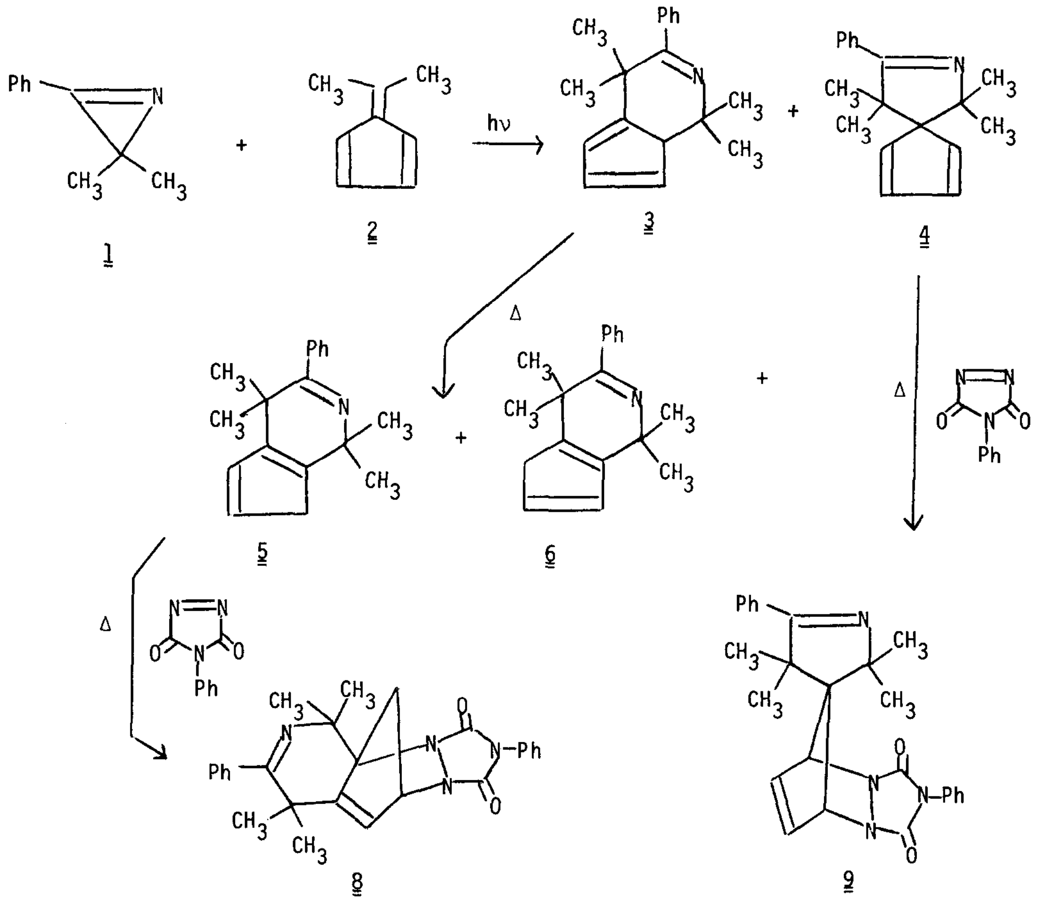
Albert Padwa* and Frederick Nobs

Department of Chemistry
State University of New York at Buffalo
Buffalo, New York 14214

(Received in USA 1 September 1977; received in UK for publication 21 November 1977)

1,3-Dipolar cycloadditions of nitrile ylides have been shown to be an astonishingly fruitful synthetic method for the preparation of a wide variety of five-membered heterocyclic rings.[1,2] These reactions can be considered to be orbital symmetry allowed $4\pi_s + 2\pi_s$ cycloadditions where the nitrile ylide, with its allyl anion type MO, functions as a 4π reactant and the dipolarophile as a 2π reactant.[3] Nitrile ylides may also cycloadd to trienes in a symmetry allowed $6\pi_s + 4\pi_s$ thermal process. It has recently been recognized by several groups of workers that the fulvene system can function as either a 2π- or 6π-addend with several different 1,3-dipoles.[4-7] These discoveries led us to investigate the photocycloaddition reactions of a representative 2H-azirine with a number of substituted fulvenes.

Irradiation of a 1:1 mixture of 3-phenyl-2,2-dimethyl-2H-azirine (1) and 6,6-dimethylfulvene (2) in cyclohexane with Vycor filtered light gave a 3:1 mixture of two cycloadducts 3 and 4. The major cycloadduct 3 [NMR ($CDCl_3$, 100 MHz) τ9.36 (s, 3H), 8.72 (s, 3H), 8.62 (s, 3H), 8.40 (s, 3H), 7.08 (s, 1H), 3.60 (m, 3H), 2.80 (m, 5H)] was quite labile and rapidly rearranged at room temperature to give a 10:1 mixture of 5 [mp 81-82°C; NMR τ8.70 (s, 6H), 8.65 (s, 6H), 6.92 (s, 2H), 3.60 (d, 1H, J = 5.0 Hz), 3.48 (d, 1H, J = 5.0 Hz) and 2.64 (s, 5H)] and 6 [oil; NMR 8.70 (s, 6H), 8.54 (s, 6H), 7.00 (s, 2H), doublets at 3.60 and 3.48 (J = 5.0 Hz) and 2.64 (s, 5H)]. The reaction of 5 with 4-phenyl-1,2,4-triazoline-3,5-dione (7) provided further evidence for the identity of the carbon skeleton of 5. The NMR spectrum of the Diels-Alder adduct 8 showed the presence of four nonequivalent methyl groups at τ8.98, 8.68, 8.48 and 8.16, the bridged protons as doublets (J = 8.0 Hz) at 8.08 and 7.64, one bridgehead proton (broad singlet) at 4.80 and a single vinylic proton (broad) at 3.76 in addition to the aromatic protons at 2.60. The formation of 5 can be readily attributed to a 1,5-sigmatropic hydrogen shift of the initially formed cycloadduct 3. It is also probable that the cyclopentadiene ring in 3 underwent two reversible [1,5]-sigmatropic hydrogen shifts to form 6.[8-10] This

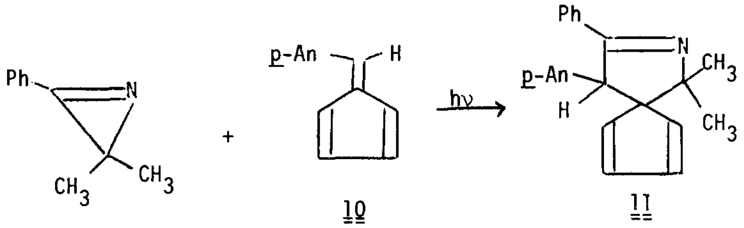


facile rearrangement is not unreasonable since many cyclopentadienes are known to undergo [1,5]-sigmatropic hydrogen shifts at room temperature.[11]

The structure of the minor adduct 4 was revealed by its spectroscopic properties [m/e 251 (M^+); uv 242 nm (ε 13000); NMR τ8.76 (*s*, 6H), 8.70 (*s*, 6H), 3.76 (*d*, 2H, J = 5.0 Hz), 3.70 (*d*, 2H, J = 5.0 Hz), 2.48-2.70 (*m*, 3H), 2.20-2.40 (*m*, 2H)] and by its conversion to cycloadduct 9 on treatment with triazoline 7 [NMR τ8.74 (*s*, 6H), 8.48 (*s*, 6H), 5.02 (broad *s*, 2H), 3.52 (broad *s*, 2H) and 2.60 (*m*, 5H)].

We also examined the photocycloaddition reaction of 6-*p*-anisylfulvene (10) with azirine 1. In this case, *p*-anisylfulvene reacts as a 2π-system to form the product of a [4+2] 1,3-dipolar cycloaddition (i.e. 11) in 17% yield along with polymeric material. The nmr spectrum of 11 is similar to that of 4 (i.e. 4-vinyl protons) suggesting an analogous structure for this adduct

[($CDCl_3$, 100 MHz) τ8.84 (s, 3H), 8.78 (s, 3H), 6.36 (s, 3H), 5.24 (s, 1H), 3.5-4.1 (m, 4H), 3.36 (d, 2H, J = 9.0 Hz), 3.14 (d, 2H, J = 9.0 Hz), 2.60-2.80 (m, 3H) and 2.20-2.40 (m, 2H)]. All attempts to induce a photocycloaddition reaction of 1 with the electron-rich 6-dimethylaminofulvene failed. The only products isolated corresponded to the previously reported photodimers of the azirine.[12]



Houk and coworkers have recently shown that a frontier orbital analysis of fulvene cycloaddition provides a good rationalization of the factors which control periselectivity.[13,14] As was noted previously, strongly HOMO controlled dipoles (i.e. nitrile ylides) should interact with the fulvene LUMO to give [6+4] cycloadducts across the 2 and 6 positions of the fulvene ring.[13] Since the fulvene LUMO has the largest coefficient at the 6-position, the 6-position should become bonded to the dipole terminus with the highest coefficient in the dipole HOMO.[15] The isolation of cycloadduct 3 is perfectly compatible with these predictions and provides the first example of a [6+4]-cycloaddition of a nitrile ylide. The inertness of 6-dimethylaminofulvene toward cycloaddition can be attributed to a raising of the LU orbital of the fulvene ring, thereby leading to an overall decrease in the frontier orbital interactions. Finally, the isolation of [4+2] cycloadducts 4 and 11 is of some interest and warrants comment. Electron deficient 1,3-dipoles generally interact with the fulvene HOMO and give [4+2] adducts across the 2 and 3 positions of the fulvene ring since the fulvene HO orbital has a node through C_6. This type of 1,3-dipolar cycloaddition would not be expected to occur here since nitrile ylides are HO-controlled dipoles. Since the coefficients at C_1 and C_2 in fulvene's LUMO are roughly of the same magnitude[14] it is not unreasonable to expect attack at either of these positions by the nitrile ylide.[16]

Acknowledgement. We wish to thank the National Cancer Institute, DHEW (CA-12195) for generous support of this work. Aid in the purchase of the XL-100 nmr spectrometer used in this work was provided by the NSF via an equipment grant.

References

1. A. Padwa, Acc. Chem. Res., 9, 371 (1976).
2. P. Gilgen, H. Heimgartner, H. Schmid and H. J. Hansen, Heterocycles, 6, 143 (1977).
3. R. B. Woodward and R. Hoffmann, "The Conservation of Orbital Symmetry", Academic Press, New York, N. Y., 1970.
4. K. N. Houk and L. J. Luskus, Tetrahedron Lett., 4029 (1970).
5. P. Caramella, P. Frattini and P. Grunanger, Tetrahedron Lett., 3817 (1971).
6. A. Quilico, P. Grunanger and R. Mazzini, Gazz Chim. Ital., 82, 349 (1952).
7. N. Dennis, B. Ibrahim and A. R. Katritzky, J. Chem. Soc. Chem. Commun., 425 (1975); J. Chem. Soc. Perkin I, 2307 (1976).
8. V. A. Mironov, V. S. Pashegorova, T. M. Fadeeva and A. A. Akhrem, Tetrahedron Lett., 3397 (1968); 3347, 3985 (1969).
9. L. L. Miller, R. Greisinger and R. F. Boyer, J. Am. Chem. Soc., 91, 1578 (1969).
10. K. N. Houk, L. J. Luskus and N. S. Bhacca, J. Am. Chem. Soc., 92, 6392 (1970).
11. V. A. Mironov, E. V. Sobolev and A. N. Elizarova, Tetrahedron, 19, 1939 (1963); E. Hedaya, D. W. McNeil, P. Schissel and D. J. McAdoo, J. Am. Chem. Soc., 90, 5284 (1968); W. R. Roth, Tetrahedron Lett., 1009 (1964); S. McLean and P. Haynes, Tetrahedron, 21, 1313 (1965).
12. A. Padwa, J. Smolanoff and S. I. Wetmore, Jr., J. Org. Chem., 38, 1333 (1973).
13. K. N. Houk, J. Sims, C. R. Watts and L. J. Luskus, J. Am. Chem. Soc., 95, 7301 (1973).
14. K. N. Houk, J. K. George and R. E. Duke, Jr., Tetrahedron, 30, 523 (1974).
15. P. Caramella and K. N. Houk, J. Am. Chem. Soc., 98, 6397 (1976).
16. It should be noted that Houk and coworkers have reported the [6+4]-cycloaddition of diethylaminobutadiene to 6,6-dimethylfulvene.[17] This reaction, which presumably proceeds through an analogous HO-diene (4π)LU-fulvene (6π) interaction, is completely periselective and does not involve competitive overlap at C_1 vs C_2. Further work is needed to account for the lack of periselectivity in the addition of nitrile ylides. One speculative possibility involves the 1,5-sigmatropic rearrangement of 3 to 4.
17. L. C. Dunn, Y. M. Chang and K. N. Houk, J. Am. Chem. Soc., 98, 7096 (1976).